PHOSPHORUS REMOVAL EFFICIENCY UPGRADING AT MUNICIPAL WASTEWATER TREATMENT PLANTS IN THE GREAT LAKES BASIN

PHASE 2
SAMPLING PROGRAM

Technical Report

FEBRUARY 1988

Canada Ontario

Canada-Ontario Agreement Respecting Great Lakes Water Quality
L'Accord Canada-Ontario relatif à la qualité de l'eau dans les Grand Lacs

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1.0 PORT DALHOUSIE (ST. CATHARINES) WATER POLLUTION CONTROL PLANT

1.1 Plant Description and Historical Performance

1.1.1 Plant Description

The Port Dalhousie WPCP is one of two major secondary treatment facilities serving the City of St. Catharines. The plant, which is operated by the Regional Municipality of Niagara, is a conventional activated sludge plant designed to handle an average daily flow of 61,300 m^3/d (13.5 MIGPD) with a peak hydraulic load of 122,600 m^3/d (27 MIGPD). A schematic flowsheet of the plant is provided in Figure 1.1. Key design parameters for the Port Dalhousie WPCP are summarized in Table 1.1.

Raw sewage enters the plant by gravity through an overflow chamber upstream of a Parshall flume for flow measurement. Screening is provided by a coarse (12.7 cm) bar screen and an automatic 2.5 cm bar screen upstream of parallel 6.1 m square detritors.

Two parallel clarifiers, each 48.8 m by 15.2 m with a liquid depth of 3.05 m, provide a total surface area of 1,490 m^2 for primary sedimentation. Total primary clarifier volume is approximately 4,600 m^3. Raw sludge and scum removal are accomplished by travelling bridge mechanisms. Waste activated sludge from the biological system is co-thickened with primary sludge in the primary clarifiers.

Biological treatment is accomplished in two parallel trains of four aeration cells. Each cell is 18.3 m square and 4.6 m deep, providing a total aeration volume of 11,030 m^3. Oxygen transfer is accomplished by 30 kW (40 HP) mechanical surface aerators, each incorporating a vertical draft tube. Total installed aeration capacity is approximately 240 kW (320 HP). Primary effluent is distributed equally to each aeration cell to an entry point under the central draft tube. Return activated sludge is distributed equally to the aeration cells.

Phosphorus removal is accomplished by ferric chloride addition to the mixed liquor upstream of the secondary clarifiers. A mechanical mixer is provided at the point of $FeCl_3$ addition; however, this supplemental mixer is not presently used. Ferric chloride is delivered by dual chemical metering pumps from two 36.3 m^3 storage tanks to the addition point. Instrumentation and control equipment is available to allow flow proportioning of $FeCl_3$ addition; however, at present the chemical feed rate is adjusted manually.

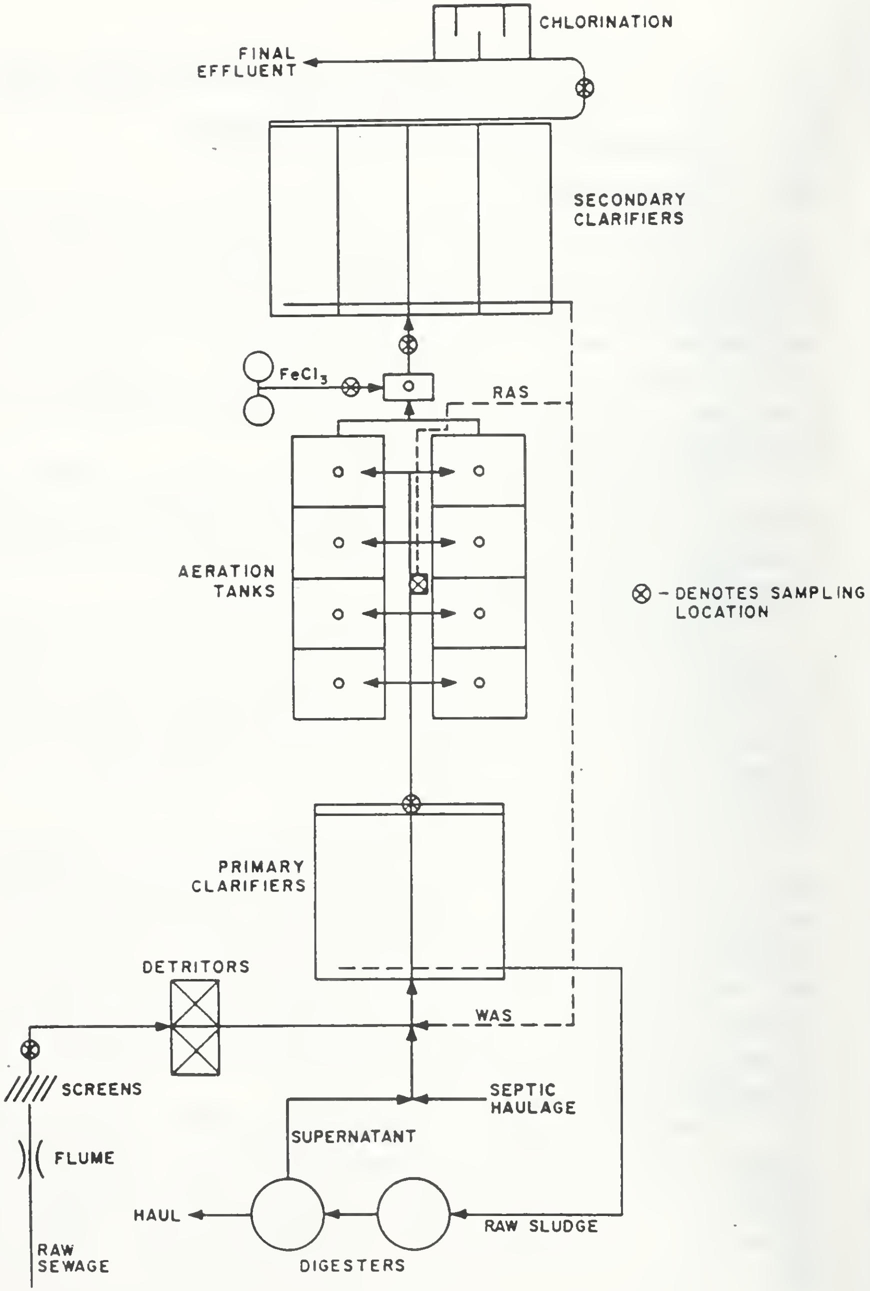


FIGURE 1-1: SCHEMATIC FLOWSHEET OF PORT DALHOUSIE WPCP

TABLE 1.1: DESIGN SUMMARY - PORT DALHOUSIE WPCP

DESIGN CRITERIA	DESIGN VALUE	OPERATING * LEVEL
Flow - m^3/d		
Average Daily	61,300	36,530
Peak Day	122,600	est 136,000
BOD_5 Loading (kg/d)	--	3,910
Sewer Collection System	Some Combined	--
Bypass - Point	Inf. Overflow	--
Frequency	--	est. 12/year
Discharge Point	Outfall	--
Primary Clarification HRT (hours)		
HRT (hours)	1.8	3.0
Average Surface Load ($m^3/m^2 \cdot d$)	41.1	24.5
Peak Surface Load ($m^3/m^2 \cdot d$)	82.3	91.4
Aeration System		
HRT (hours)	4.3	7.2
BOD_5 Load ($kg/m^3 \cdot d$)**	--	0.21
Return Sludge Rate (%)	100	--
Phosphorus Removal		
Chemical	$FeCl_3$	--
Average Dosage (mg Fe/L)	--	1984=8.2 mg/L 1985=6.6 mg/L
Secondary Clarification		
HRT (hours)	4.7	7.9
Avg. Surface Loading ($m^3/m^2 \cdot d$)	19.1	11.4
Peak Surface Loading ($m^3/m^2 \cdot d$)	38.1	42.3
Chlorination		
HRT @ Peak Flow, (min)	10.0	9.0

* Based on 1981-1985 Historical Data.

** At 40 percent primary clarifier BOD removal.

Secondary clarification is accomplished in four parallel 67m by 12m rectangular clarifiers providing a total surface area of 3,216 m^2 and a total liquid volume of 11,970 m^3. The sludge removal mechanisms are floating travelling bridges. Return sludge is handled by two screw pumps, each transferring 21.3 m^3/min and providing 100 percent recycle sludge capability at design flow. Secondary effluent is chlorinated prior to discharge to Lake Ontario.

Two-stage anaerobic digestion is provided for waste activated sludge and primary sludge. Two primary digesters provide a total volume of 4,000 m^3. The secondary digester provides a total volume of 2,000 m^3. Digested sludge is disposed on land.

1.1.2 Historical Performance

Table 1.2 summarizes the annual performance of the Port Dalhousie WPCP for the years 1981 to 1985. The plant has consistently achieved a high quality effluent, averaging approximately 8 mg/L total BOD_5 and suspended solids and 0.55 mg/L total phosphorus for the five year period (1981 - 1985). Influent strength has been relatively low (110 mg/L BOD_5, 100 mg/L suspended solids and 4.2 mg/L total phosphorus). Average daily flow to the plant for the five-year period was 36,530 m^3/d (59.5 percent of design flow).

Monthly effluent quality data for 1984 and 1985 (BOD_5, suspended solids and total phosphorus) are presented in Table 1.3. Effluent phosphorus levels have consistently been less than 1.0 mg/L. Effluent suspended solids exceeded 15 mg/L for one month (November 1985) and never exceeded 25 mg/L. Effluent BOD_5 exceeded 15 mg/L for five months and exceeded 25 mg/L for one month (May 1985) during this period.

1.1.3 Sampling Program

The Port Dalhousie WPCP was sampled between June 23, 1986 and July 25, 1986. Twelve daily samples were collected over this monitoring period.

Sampling locations were identified in Figure 1.1. Twenty-four hour composite samples of raw wastewater (after screening) and primary effluent were collected. Flow-proportional, 24-hour composite samples of secondary effluent (before chlorination) were collected. In addition, grab samples of mixed liquor and return sludge were collected to allow SRT calculations to be completed.

TABLE 1.2: ANNUAL AVERAGE PERFORMANCE OF PORT DALHOUSIE WPCP

PARAMETER	YEAR					5 YEAR AVERAGE 81-85
	1981	1982	1983	1984	1985	
Average Daily Flow (1,000 m^3/d)	35.50	36.79	36.32	32.43	41.59	36.5
BOD_5 - Influent (mg/L)	90.5	100.0	119.0	99.7	128.1	107.5
BOD_5 - Effluent (mg/L)	9.2	7.0	4.0	7.7	11.5	7.9
TSS - Influent (mg/L)	102.6	92.0	103.0	96.5	117.8	102.4
TSS - Effluent (mg/L)	9.9	7.0	6.9	7.5	10.6	8.4
Total P - Influent (mg/L)	4.20	4.40	4.27	4.11	3.89	4.17
Total P - Effluent (mg/L)	0.58	0.70	0.53	0.55	0.39	0.55

TABLE 1.3: MONTHLY AVERAGE PERFORMANCE OF PORT DALHOUSIE WPCP

YEAR	MONTH	EFFLUENT BOD_5 (mg/L)	n BOD_5	EFFLUENT TSS (mg/L)	n TSS	EFFLUENT TP (mg/L)	n TP
1984	Jan.	5.2	2	7.6	32	0.74	6
	Feb.	13.8	2	12.1	32	0.88	6
	Mar.	5.2	2	7.1	32	0.33	6
	Apr.	18.5	2	6.7	32	0.55	6
	May	3.3	2	7.7	32	0.42	6
	June	4.9	2	7.2	30	0.50	6
	July	8.0	2	6.8	31	0.40	4
	Aug.	6.0	2	6.8	31	0.52	4
	Sept.	4.8	2	6.5	30	0.72	4
	Oct.	3.2	2	6.7	31	0.64	4
	Nov.	7.2	2	7.4	31	0.35	4
	Dec.	11.8	2	7.4	31	0.54	4
1985	Jan.	9.1	2	7.2	32	0.33	4
	Feb.	15.3	2	13.0	29	0.38	4
	Mar.	22.0	2	10.9	31	0.45	5
	Apr.	15.6	2	8.9	30	0.32	4
	May	27.0	2	9.1	31	0.52	4
	June	5.3	2	8.1	31	0.50	4
	July	3.5	2	10.8	31	0.42	3
	Aug.	9.0	2	7.7	31	0.24	5
	Sept.	5.0	2	7.7	31	0.34	5
	Oct.	6.0	2	11.5	31	0.54	5
	Nov.	12.9	2	21.5	30	0.35	3
	Dec.	7.0	2	11.2	31	0.25	5

n = Number of samples

1.2 Results of Sampling Program

Table 1.4 presents a compilation of plant operating data, supported by CANVIRO data, for the five-week period of sampling at the Port Dalhousie WPCP. Average daily flow for this period, which included several significant rainfall events, was 46,000 m^3/d or 75 percent of plant design. This flow was significantly higher than observed during 1985 (41,590 m^3/d or 68 percent of design). Peak flows in excess of 100,000 m^3/d were observed on two occasions during this period.

The biological system was operated in a stable mode by constant wasting. Solids retention time (SRT) was consistently around 5 days, averaging 4.9 days over the 5-week period. Historical data for 1985 has shown that the plant achieves a high degree of nitrification. Influent TKN concentrations averaged 24.8 mg/L in 1985. Average effluent TKN was 6.0 mg/L and average effluent NH_3-N was 3.57 mg/L for the same period. Minimal plant data showed that nitrification was occurring during the June/July monitoring period with an effluent quality of 1.35 mg/L NH_3-N and 2.2 mg/L TKN recorded in June.

Ferric chloride was added at a constant rate of 2,270 L/d throughout the monitoring period. Samples from six batches of ferric chloride showed an average iron (Fe) content of 145.3 g/L (± 16.1), equivalent to a ferric chloride strength of approximately 32 percent $FeCl_3$ (w/w). The calculated chemical dosage averaged 7.2 mg Fe/L for the 5-week period, ranging from 4.5 mg/L to 9.6 mg/L.

The results of the monitoring program are summarized in Table 1.5. Raw wastewater strength, in terms of all parameters, was low compared to historical data. The raw wastewater averaged 44 mg/L BOD_5 and 69 mg/L suspended solids. Influent total phosphorus levels averaged 3.13 mg/L, of which approximately 66 percent was presented in soluble form. The lower strength wastewater is consistent with the higher flows experienced during the monitoring period caused by rainfall and the difference in sampling procedures. Historical data (influent and effluent) has been based on 12-hour manual composite whereas the influent data in Table 1.5 represents 24-hour composite sampling results. Effluent quality during the monitoring period confirms the historical pattern of superior performance. Average effluent BOD_5 was 3.5 mg/L. Average effluent suspended solids concentration was 10 mg/L. The total phosphorus in the secondary effluent was 0.77 mg/L, of which 0.50 mg/L

TABLE 1.4: SUMMARY OF PORT DALHOUSIE WPCP OPERATING CONDITIONS (June 23 - July 27/86)

DATE (1986)	FLOW ($m^3/d \times 10^3$)			BYPASS (HR)	MLSS (mg/L)	MLVSS (%)	RAS (mg/L)	WAS (m^3)	$FeCl_3$* (L/d)	Fe DOSAGE (mg/L)	SRT (days)	COMMENT
	TOTAL	MAX.	MIN.									
June 23	45.9	49.9	26.3		2840	59.2	9140	1160	2270	7.2		RAIN
24	46.3	86.3	26.3		2694	57.4	8780	1160	2270	7.1		RAIN
25	41.8	47.7	26.3		3579	58.0	6886	1160	2270	7.9		
26	39.5	45.4	22.7		3248	63.3	5716	1160	2270	8.3	4.3	
27	46.9	86.3	22.7	1.0	3304	57.9	5020	1160	2270	7.0		RAIN
28	36.3	42.7	22.7		4241	58.8	6614	1160	2270	9.1		
29	34.2	39.5	20.9		4284	59.4	6650	1160	2270	9.6		
30	34.7	40.9	20.4		3160	58.2	6680	1160	2270	9.5		
July 1	37.8	43.1	22.7		3180	58.5	6580	1160	2270	8.7		
2	44.5	69.5	27.2		3245	59.0	6700	1160	2270	7.4		
3	43.4	104.4	22.7		2840	59.2	6400	1160	2270	7.6	4.6	
4	38.8	45.4	22.7		3190	58.9	8180	1160	2270	8.5		DRIZZLE
5	35.1	40.9	19.5		3030	60.4	3540	1160	2270	9.4		
6	34.1	38.6	20.4		3280	62.3	7460	1160	2270	9.7		
7	56.3	90.8	22.7	6.5	2686	60.0	5178	1160	2270	5.8		RAIN
8	47.5	54.5	31.8		3210	60.0	6640	1160	2270	6.9		
9	42.4	49.9	27.2		2538	55.9	5642	1160	2270	7.7		
10	41.8	49.9	31.8		3195	58.5	4442	1160	2270	7.9	4.8	
11	41.9	49.9	27.2		2512	26.1	3324	1160	2270	7.9		
12	63.6	>90.8	26.3		2291	58.8	5112	1160	2270	5.2		RAIN
13	52.2	72.6	29.1		2985	56.3	5707	1160	2270	6.3		RAIN
14	53.6	86.3	32.7		7774	71.4	6972	1160	2270	6.1		
15	43.9	54.5	27.2		3062	56.1	5094	1160	2270	7.5		
16	42.9	54.7	25.4		2500	55.8	4978	1160	2270	7.7		
17	55.4	93.1	22.7	3.0	4194	58.0	4622	1160	2270	5.9	5.2	RAIN
18	73.1	104.4	40.9	4.5	2659	56.8	6888	1160	2270	4.5		RAIN
19	72.8	99.9	49.9	1.8	2846	51.2	6778	1160	2270	4.5		RAIN
20	48.3	58.1	35.4		2830	52.2	9100	1160	2270	6.8		
21	47.8	61.3	29.5		3070	52.4	6560	1160	2270	6.9		
22	45.4	54.5	28.1		2740	54.7	12300	1160	2270	7.3		
23	45.1	54.5	27.2		3510	54.7	3592	1160	2270	7.3		
24	45.6	56.8	29.5		3341	53.4	3588	1160	2270	7.2	5.4	
25	45.5	56.8	28.1		3452	55.2	5452	1160	2270	7.2		
26	43.3	49.9	28.1		3771	55.7	3182	1160	2270	7.6		
27	41.2	46.8	27.2		4329	64.5	6601	1160	2270	8.0		DRIZZLE
AVG.	46.0	-	-	-	3300	58.6	6225	1160	2270	7.2	4.9	
MAX.	73.1	104.4	49.9	-	7774	-	12300	-	-	9.6	-	
MIN.	34.1	38.6	19.5	-	2500	-	3182	-	-	4.5	-	

TABLE 1.5: SUMMARY OF PERFORMANCE MONITORING DATA FOR PORT DALHOUSIE WPCP

DATE	STREAM	CONCENTRATION			
		TOTAL BOD_5	TSS	TOTAL PHOSPHORUS	SOLUBLE PHOSPHORUS
23/06	Raw	100	100	3.54	2.84
	Primary Effluent	-	-	2.87	1.13
	Secondary Effluent	3.3	22	0.72	0.28
24/06	Raw	58	120	2.68	2.06
	Primary Effluent	-	-	N.A.	0.51
	Secondary Effluent	4.6	8	0.35	0.18
14/07	Raw	54	60	3.18	1.96
	Primary Effluent	-	-	4.00	1.50
	Secondary Effluent	2.3	10	0.75	0.50
15/07	Raw	42	50	3.92	2.49
	Primary Effluent	-	-	3.70	1.84
	Secondary Effluent	4.9	10	1.03	0.63
16/07	Raw	63	70	3.08	2.50
	Primary Effluent	-	-	4.76	1.95
	Secondary Effluent	3.1	8	1.10	0.68
17/07	Raw	35	90	2.52	1.69
	Primary Effluent	-	-	2.07	0.92
	Secondary Effluent	2.4	7	0.58	0.53
18/07	Raw	10	60	1.98	1.28
	Primary Effluent	-	-	2.18	2.19
	Secondary Effluent	3.0	7	0.60	0.48
21/07	Raw	14	30	2.94	1.88
	Primary Effluent	-	-	4.40	0.93
	Secondary Effluent	3.0	12	0.88	N.A.
22/07	Raw	24	40	3.12	2.15
	Primary Effluent	-	-	3.30	1.86
	Secondary Effluent	2.7	4	0.67	0.45
23/07	Raw	45	90	3.70	2.14
	Primary Effluent	-	-	4.30	1.85
	Secondary Effluent	5.1	6	0.68	0.53
24/07	Raw	38	50	3.19	2.20
	Primary Effluent	-	-	2.97	1.98
	Secondary Effluent	3.0	10	0.74	0.49
25/07	Raw	42	70	3.80	1.47
	Primary Effluent	-	-	3.60	2.15
	Secondary Effluent	4.6	16	1.09	0.72
AVERAGES	Raw	43.8	69.1	3.13	2.06
	Primary Effluent	-	-	3.47	1.57
	Secondary Effluent	3.5	10.0	0.77	0.50
Std.Devs	Raw	24.1	26.4	0.56	0.44
	Primary Effluent	-	-	0.88	0.56
	Secondary Effluent	1.0	4.9	0.22	0.16

was present in soluble form. Probability distributions of the total and soluble components of the phosphorus in raw sewage, primary effluent and secondary effluent are presented in Figure 1.2. Primary clarification did not reduce the total phosphorus concentration.

Key operating parameters affecting phosphorus removal at the Port Dalhousie WPCP are summarized in Table 1.6. Clarifier hydraulic loadings were generally low, averaging approximately 15 $m^3/m^2 \cdot d$ (310 $Igpd/ft^2$). The low hydraulic loading, along with good sludge settleability (SVI < 120), produced low effluent suspended solids concentrations. Thus, phosphorus associated with the particulate matter in the effluent contributed only 0.26 mg/L to the total phosphorus concentration. Based on soluble phosphorus in the primary effluent, the average Fe:P molar ratio was 2.9, compared to the stoichiometric requirement of 1. Thus, the chemical dosage, which averaged 6.8 mg Fe/L, was relatively high and resulted in a low soluble phosphorus concentration (0.50 mg/L) in the secondary effluent.

1.3 Conclusions of Port Dalhousie WPCP Monitoring Program

The five-week monitoring program at Port Dalhousie WPCP confirmed the high effluent quality reported historically at this plant in terms of BOD_5, suspended solids and total phosphorus. Raw wastewater strength was lower than had been reported, due to rainfall and the different sampling methodology applied in this study.

The major factors contributing to the efficient phosphorus removal program at Port Dalhousie were:

(i) low secondary clarifier hydraulic loadings;
(ii) high iron dosage; and
(iii) good operational control of the plant, in general.

Although ferric chloride addition rates are seldom, if ever, changed, effective control of effluent total phosphorus is maintained because there is relatively little change in the particulate phosphorus content of the effluent, there is minimal variation in influent concentration and there is a reserve of iron in the system because of the relatively high dosage maintained.

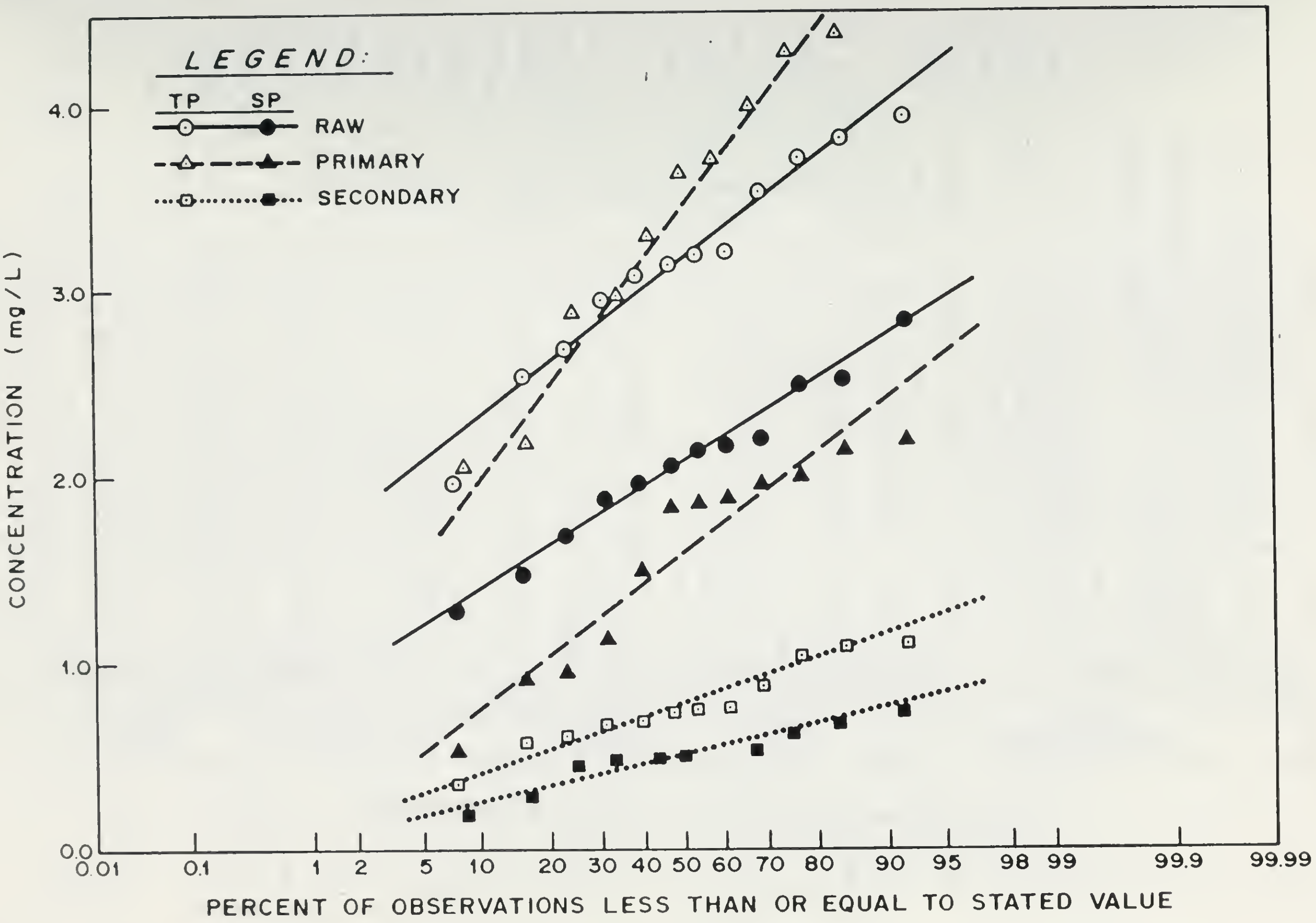


FIGURE 1-2: PROBABILITY DISTRIBUTIONS FOR PHOSPHORUS DATA AT THE PORT DALHOUSIE WPCP

TABLE 1.6: SUMMARY OF KEY OPERATING PARAMETERS FOR PORT DALHOUSIE WPCP

DATE	FLOW (10^3 m^3/d)		CLARIFIER LOAD ($m^3/m^2 \cdot d$)		Fe DOSE (mg/L)	PRIMARY CLAR. SOL. P. (mg/L)	Fe:P RATIO *		EFFLUENT QUALITY (mg/L)			
	AVERAGE	PEAK	AVERAGE	PEAK			WEIGHT	MOLAR.	TSS	TP	SOL. P.	PART P.
23/06	45.9	49.9	14.3	15.5	7.2	1.13	6.4	3.5	22	0.72	0.28	0.44
24/06	46.3	86.3	14.4	26.8	7.1	0.51	13.9	7.7	8	0.35	0.18	0.17
14/07	53.6	86.3	16.7	26.8	6.1	1.50	4.1	2.3	10	0.75	0.50	0.25
15/07	43.9	54.5	13.7	16.9	7.5	1.84	4.1	2.3	10	1.03	0.63	0.40
16/07	42.9	52.7	13.3	16.4	7.7	1.95	3.9	2.2	8	1.10	0.68	0.42
17/07	55.4	93.1	17.2	28.9	5.9	0.92	6.4	3.5	7	0.58	0.53	0.05
18/07	73.1	104.4	22.7	32.5	4.5	2.19	2.1	1.2	7	0.60	0.48	0.12
21/07	47.8	61.3	14.9	19.1	6.9	0.93	7.4	4.1	12	0.88	--	--
22/07	45.4	54.5	14.1	16.9	7.3	1.86	3.9	2.2	4	0.67	0.45	0.22
23/07	45.1	54.5	14.0	16.9	7.3	1.85	3.9	2.2	6	0.68	0.53	0.15
24/07	45.6	56.8	14.2	17.7	7.2	1.98	3.6	2.0	10	0.74	0.49	0.25
25/07	45.5	56.8	14.1	17.7	7.2	2.15	3.3	1.8	16	1.09	0.72	0.37
AVERAGE	49.2	67.6	15.3	21.0	6.8	1.57	5.3	2.9	10	0.77	0.50	0.26

*Based on primary effluent soluble phosphorus concentration

2.0 FERGUS WATER POLLUTION CONTROL PLANT

2.1 Plant Description and Historical Performance

2.1.1 Plant Description

The Fergus WPCP, an MOE operated plant, serves the City of Fergus (population 5,935 in 1985). Approximately 70 percent of the flow to the plant is domestic, while the remaining 30 percent is contributed from local industries. The plant is a conventional activated sludge plant designed to handle an average daily flow of 5,000 m^3/d. Figure 2.1 presents a schematic of the treatment plant. Key design paramaters are summarized in Table 2.1.

Raw sewage enters the plant through a comminutor. Grit is removed in a detritor upstream of a Parshall flume for flow measurement. Flow enters a single square primary clarifier with 12.2 m sides and 2.7 m side wall depth, providing a total surface area of 161.3 m^2 for sedimentation. The total primary clarifier volume is approximately 435 m^3. Waste activated sludge from the biological system is co-thickened with primary sludge in the primary clarifier.

Following primary treatment, the flow is divided into two streams. Approximately 60 percent of the flow enters the old secondary treatment system and 40 percent enters the new secondary treatment system. Phosphorus removal is accomplished by ferrous chloride addition to the primary clarifier effluent just prior to the flow division to "new" and "old" secondary systems. The chemical feed rate is adjusted manually on a daily basis. Chemical flow is increased or decreased based on extreme phosphosrus concentrations in effluents, although chemical usage is calculated on a weekly basis. The old and new secondary aeration and clarification systems are operated in parallel. The old aeration tanks provide at total volume of 512 m^3 (21.9 m x 7.3 m x 3.2 m); the new tanks provide at total volume of 592 m^3 (21.9 m x 7.3 m x 3.7 m). Both systems have 2 celled, mechanically aerated aeration basins. Return activated sludge from each secondary clarifier is return to the front end of the respective aeration tanks.

Secondary clarification in the parallel systems is provided in square 10.7 m by 10.7 m by 2.7 m clarifiers, providing a total surface area (for each system) of 114 m^2 and total liquid volume of 309 m^3. Return activated sludge from each clarifier is pumped at a constant rate (570 m^3/d)

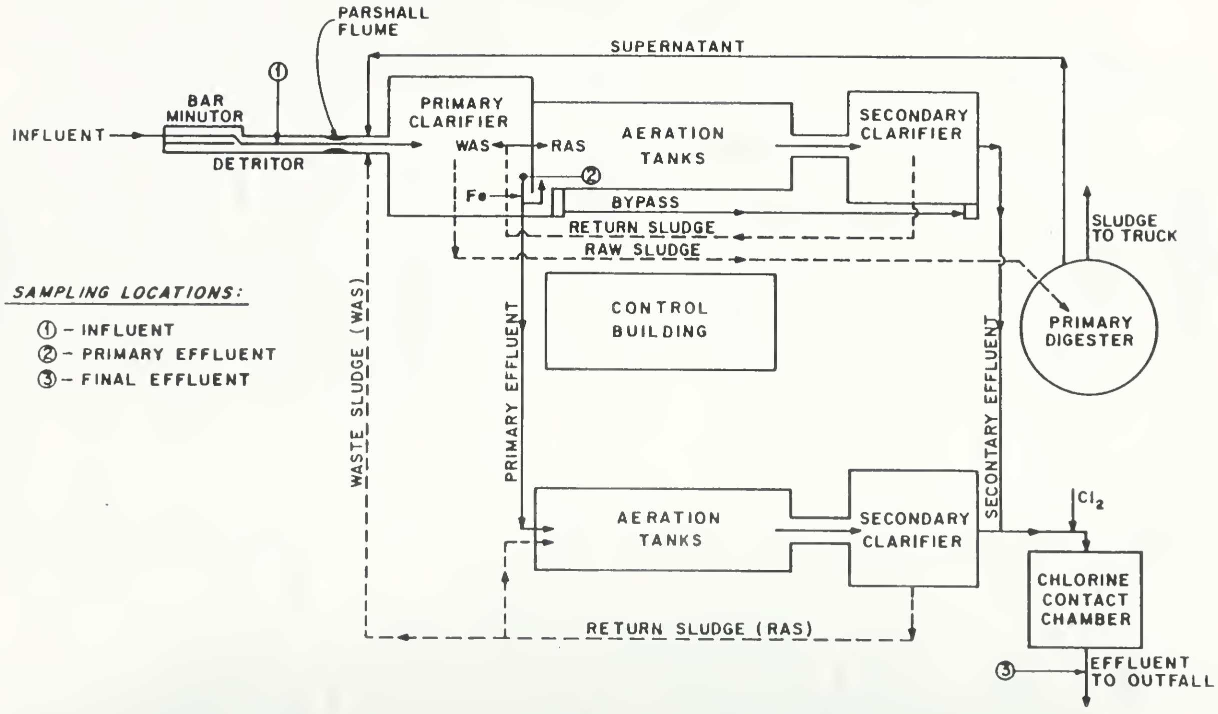


FIGURE 2-1: SCHEMATIC OF FERGUS WPCP

TABLE 2.1: DESIGN SUMMARY - FERGUS WPCP

DESIGN CRITERIA	DESIGN VALUE	OPERATING LEVEL *	
FLOW (m^3/d)			
AVERAGE DAILY	5,000	3420	
PEAK DAY	--	est. 9100	
BOD LOADING (kg/d)	1,000	403	
SEWER COLLECTION SYSTEM	<10% combined	--	
BYPASS - POINT	influent wetwell		
FREQUENCY		10/year	
DISCHARGE POINT	outfall	--	
PRIMARY CLARIFICATION			
HRT (Hours)	2.0	2.9	
AVG SURFACE LOAD (m^3/m^2.d)	35.6	24.3	
PEAK SURFACE LOAD (m^3/m^2.d)		64.8	
AERATION SYSTEM		Old	New
HRT (Hours)	5.9	5.98	9.95
BOD LOAD (kg/m^3.d)**	0.33	0.13	
RETURN SLUDGE RATE (%)	--	30	
PHOSPHORUS REMOVAL			
CHEMICAL	$FeCl_2$	--	
AVERAGE DOSAGE (mg Fe/L)	--	5.1 (1984, 1985)	
SECONDARY CLARIFICATION		Old	New
HRT (Hours)	3.0	3.6	5.4
AVG. SURFACE LOAD (m^3/m^2.d)	22.0	17.9	11.9
PEAK SURFACE LOAD (m^3/m^2.d)	--	47.7	31.8
CHLORINATION			
HRT @ PEAK FLOW (min)	--	18.7	

*Based on 1981 - 1985 historical data.

**At 40% BOD_5 removal in primary clarifiers.

to the front end of each of the new and old systems. If sludge is being wasted, return sludge flow is split in individual splitter boxes and is returned to the primary clarifier for thickening. Secondary effluent from each system is combined prior to chlorination, and chlorinated effluent is discharged to the Grand River.

Anaerobic digestion is provided for the thickened waste activated sludge/primary sludge from the primary clarifiers in a single stage anaerobic digestion of 602 m^3 total volume. Digested sludge is hauled away to be disposed of on land.

2.1.2 Historical Performance

Table 2.2 summarizes the annual performance of the Fergus WPCP for the years 1981 to 1985. Over the 5 year period, the plant has consistantly achieved a high quality effluent with respect to BOD_5, averaging 9 mg/L, and total phosphorus, averaging 0.63 mg/L. Effluent TSS averaged 17.4 mg/L. Influent strength has remained relatively steady over the 5 year period, averaging 118 mg/L BOD_5, 148 mg/L TSS and 5.81 mg/L total phosphorus. The average daily flow to the plant for the 5 year period was 3420 m^3/d, 68.4 percent of design flow.

Monthly effluent quality data for 1984 and 1985 (BOD_5, suspended solids and total phosphorus) are presented on Table 2.3. Effluent total phosphorus levels were consistantly less than 0.85 mg/L despite suspended solids concentrations of up to 34 mg/L. Monthly average effluent BOD_5 concentrations exceeded 15 mg/L for 5 months, but never exceeded 25 mg/L in the 2 year period. Effluent TSS exceeded 25 mg/L for three months in 1984 and for five months in 1985.

2.1.3 Sampling Program

The Fergus WPCP was sampled between 18 June and 10 July, 1986. Twelve daily samples were collected over the monitoring period. It should be noted that samples were not collected on weekends or during local industry shut downs so that plant influent strengths and flows were typical.

Sampling locations were identified on Figure 2.1. Twenty-four hour composite samples of raw wastewater (after grit removal) and primary effluent were collected. Flow proportioned 24-hour composite samples of chlorinated secondary effluent were collected. Mixed liquor suspended solids analyses

TABLE 2.2. ANNUAL AVERAGE PERFORMANCE OF FERGUS WPCP

PARAMETER	YEAR					5 YEAR AVERAGE 81 - 85
	1981	1982	1983	1984	1985	
Avg. Daily Flow (1000 m^3/d)	2.99	3.31	3.20	3.74	3.88	3.42
BOD_5 - Influent (mg/L) BOD_5 - Effluent (mg/L)	114.0 6.9	97.5 7.0	119.5 9.5	137.3 10.5	120.3 10.2	117.8 8.9
TSS - Influent (mg/L) TSS - Effluent (mg/L)	153.7 13.0	119.9 15.9	137.5 16.6	150.3 17.2	132.3 24.5	147.8 17.4
Total P - Influent (mg/L) Total P - Effluent (mg/L)	7.5 0.6	4.97 0.64	5.60 0.64	6.17 0.65	4.88 0.55	5.81 0.63

TABLE 2.3 MONTHLY AVERAGE PERFORMANCE OF FERGUS WPCP

Year	Month	Effluent BOD_5 (mg/L)	n BOD	Effluent TSS (mg/L)	n TSS	Effluent TP (mg/L)	n TP
1984	Jan.	9.9	1	21.2	21	0.64	32
	Feb.	8.4	2	13.7	2	0.54	31
	Mar.	17.1	2	10.9	22	0.65	33
	Apr.	9.3	2	10.0	19	0.67	32
	May	4.5	2	12.3	24	0.64	33
	June	8.6	2	12.3	23	0.81	32
	July	5.9	1	14.8	21	0.73	32
	Aug.	16.0	1	15.4	23	0.69	32
	Sept.	9.9	2	25.1	21	0.63	32
	Oct.	16.2	2	29.8	24	0.67	33
	Nov.	8.3	2	27.0	23	0.34	32
	Dec.	12.5	1	13.5	20	0.75	31
1985	Jan.	19.7	2	33.8	24	0.82	33
	Feb.	14.4	3	31.8	23	0.58	31
	Mar.	12.4	2	31.6	23	0.49	33
	Apr.	15.9	2	19.7	2	0.49	32
	May	10.2	2	22.2	24	0.61	33
	June	7.2	2	18.8	22	0.59	32
	July	6.7	1	23.3	22	0.66	32
	Aug.	10.2	1	18.9	22	0.72	32
	Sept.	4.9	2	20.1	22	0.42	32
	Oct.	5.6	2	33.6	24	0.48	33
	Nov.	9.3	2	13.2	22	0.39	32
	Dec.	5.5	1	27.4	20	0.36	32

n - number of samples

conducted on site by plant staff at Fergus WPCP were recorded. Occasional grab samples of return sludge were taken to allow SRT calculations to be carried out.

2.2 Results of Sampling Program

Table 2.4 presents a summary of operating data for the twelve days the plant was sampled. The average daily flow for these days was 3,697 m^3/d or 73.9 percent of design flow. The maximum instantaneous peak flow of 6,916 m^3/d occurred on 23 June 1986. This was much less than the estimated annual daily peak flow of 9100 m^3/d.

Sludge was wasted 6 days for the entire 23 days between the start and end of sampling, resulting in an average waste sludge flow of 37.7 m^3/d. The solids retention time achieved during this period averaged about 13.6 days. Historical monthly data for 1985 has shown that the plant achieves a high degree of nitrification. Influent TKN concentrations (in 1985) averaging 30.0 mg/L were reduced to an average effluent (1985) concentration of 2.73 mg/L. Although there were no data available for nitrification during the sampling period, MLSS and sludge wasting rates from 1985 are consistent with those measured during the sampling period. The long SRT during the sampling period was similar to the SRT maintained during 1985 and found to be conducive to nitrification.

Ferrous chloride was added continuously to the primary effluent. Although the chemical flow rate may have been adjusted daily, dosage was calculated on a weekly basis. The daily chemical usage could not be accurately measured due to the extremely small height increment in the liquid level in the chemical tank. The concentration of iron in one grab sample of ferrous chloride from the batch used during the sampling period was found to be 6.6%. This compared to a concentration reported by plant staff of 6.5% Fe. The weight of Fe^{2+} and dosages used were based on the weekly chemical volume used (at 6.5% Fe) and average daily flow, as calculated by plant staff.

For the 12 days sampled, the raw wastewater had average concentrations of 73 mg/L BOD_5, 171 mg/L suspended solids and 3.84 mg/L total phosphorus, of which approximately 55 percent was in soluble form. The final effluent had average concentrations of 4.6 mg/L BOD_5, 12.6 mg/L suspended solids and 0.59 mg/L total phosphorus, of which approximately 71 percent was in soluble form.

TABLE 2.4. SUMMARY OF FERGUS WPCP OPERATING CONDITIONS DURING SAMPLING PERIOD

DATE (1986)	FLOW (m^3/d)		BYPASS	OLD SYSTEM			NEW SYSTEM			RAS (mg/L)	WAS (m^3)	Fe^{2+} (kg)	Fe^{2+} DOSAGE (mg/L)	SRT
	TOTAL	MAX.		MLSS (mg/L)	MLVSS (%)	SVI	MLSS (mg/L)	MLVSS (%)	SVI					
18/6	3,921	4,823	no	1,345		82	1,335		75		0	11.61	2.96	13.6
19/6	3,890	4,778	no	1,615	60.1	81	1,425	58.9	77	2,520	0	11.61	2.98	
23/6	4,330	6,916	no	1,837		93	1,957		77		113	16.37	3.78	
24/6	3,945	5,005	no	2,280		83	1,404		71		113	16.37	4.15	
25/6	3,823	4,778	no	1,292		85	1,666		72		0	16.37	4.28	
26/6	3,805	5,051	no	1,400	63.8	100	1,572	62.4	76	3,290	0	16.37	4.30	
3/7	3,539	4,459	no	1,724		79	2,570		87		113	24.94	7.05	
4/7	3,397	4,459	no	1,312		84	1,260		95		0	24.94	7.34	
7/7	3,550	4,823	no	2,444		74	1,636		86		113	16.34	4.60	
8/7	3,469	4,778	no	1,407	54.2	78	1,855	56.1	70	2,820	0	16.34	4.71	
9/7	3,298	4,095	no	1,600		81	1,802		78		0	16.34	4.95	
10/7	3,397	4,596	no	2,000		80	1,895		71		0	16.34	4.81	
AVG.	3,697	4,880	none	1,688		83	1,698		80	2,877	37.7	17.00	4.66	13.6

The results of the monitoring program are summarized in Table 2.5. The raw wastewater strength in terms of BOD_5 and total phosphorus was low compared to historical data. Effluent BOD_5 concentrations were lower than historical data, but effluent total phosphorus concentrations were comparable. Influent suspended solids concentrations were typically higher than historical data. However, good suspended solids removal in the plant resulted in an average suspended solids concentration that was lower than the average for any of the five years (1981 - 1985).

One possible reason for the discrepancies between the historical data and the sampling data is the difference in sampling methodology. Historical data for BOD_5, influent suspended solids and influent total phosphorus were based on two 8-hour manually composited samples per month. Effluent suspended solids and phosphorus samples were also collected by this approach, and averaged with grab sample results from samples collected at 8.00 A.M. each day. Thus, night flow periods (5 P.M. to 8 A.M.) were not included in historical data. Samples collected for this study were all 24 hour composite samples. Despite the different sampling methods, the effluent quality found for this study confirms the historical pattern of superior performance in terms of BOD_5 and total phosphorus. The results also suggest that the actual effluent suspended solids concentrations may be lower than historically reported data due to the effect of night flows not taken into account in the historic data.

Probability distributions of the soluble phosphorus in raw sewage, primary effluent and final effluent are presented in Figure 2.2. Extrapolation of the data in Figure 2.2 shows a 95 percent probability that influent soluble phosphorus concentrations will be less than 3.6 mg/L, and effluent soluble phosphorus concentrations will be less than 0.76 mg/L.

Key operating parameters affecting phosphorus removal at the Fergus WPCP are summarized in Table 2.6. Total daily flows averaged only 74 percent of design values, resulting in a low average clarifier surface load of 16.3 $m^3/m^2.d$. The low clarifier surface load, and good sludge settleability (average SVI of 81) produced an average effluent suspended solids concentration of 12.1 mg/L. Phosphorus concentrations associated with particulate matter were therefore low, averaging 0.17 mg/L.

TABLE 2.5. SUMMARY OF PERFORMANCE MONITORING DATA FOR FERGUS WPCP

DATE	STREAM	CONCENTRATION			
		BOD_5	TSS	Total P	Sol. P
18/6	Raw	80	170	3.50	1.9
	Primary Effluent	-	-	3.10	1.8
	Final Effluent	4	10	0.57	0.51
19/6	Raw	70	220	3.71	1.54
	Primary Effluent	-	-	2.08	1.17
	Final Effluent	4.8	12	0.68	0.64
23/6	Raw	90	180	3.74	1.68
	Primary Effluent	-	-	1.73	1.42
	Final Effluent	3.8	9	0.48	0.41
24/6	Raw	70	220	3.26	2.10
	Primary Effluent	-	-	2.70	1.82
	Final Effluent	-	7	0.26	0.22
25/6	Raw	62	160	5.84	1.47
	Primary Effluent	-	-	2.17	1.54
	Final Effluent	3.4	6	0.37	0.30
26/6	Raw	73.6	260	3.27	1.71
	Primary Effluent	-	-	3.50	1.77
	Final Effluent	2.7	10	0.50	0.32
3/7	Raw	61	240	3.90	1.81
	Primary Effluent	-	-	2.30	1.28
	Final Effluent	2.1	16	0.53	0.37
4/7	Raw	63.7	180	3.43	2.07
	Primary Effluent	-	-	2.43	1.33
	Final Effluent	3.3	16	0.48	0.32
7/7	Raw	104	170	4.90	2.36
	Primary Effluent	-	-	4.54	1.40
	Final Effluent	4.9	33	0.91	0.63
8/7	Raw	85.7	120	3.60	3.44
	Primary Effluent	-	-	3.32	0.94
	Final Effluent	8.8	14	1.03	0.57
9/7	Raw	38	30.7	3.40	2.33
	Primary Effluent	-	-	4.08	1.15
	Final Effluent	7.4	5.2	0.62	0.40
10/7	Raw	73	102	3.50	3.10
	Primary Effluent	-	-	3.92	1.08
	Final Effluent	5.9	-	0.59	0.36
Averages	Raw	72.6	171	3.84	2.13
	Primary Effluent	-	-	2.99	1.39
	Final Effluent	4.6	12.6	0.59	0.42
Standard Dev.	Raw	16.7	63.8	0.77	0.61
	Primary Effluent	-	-	0.89	0.29
	Final Effluent	2.0	7.7	0.21	0.14

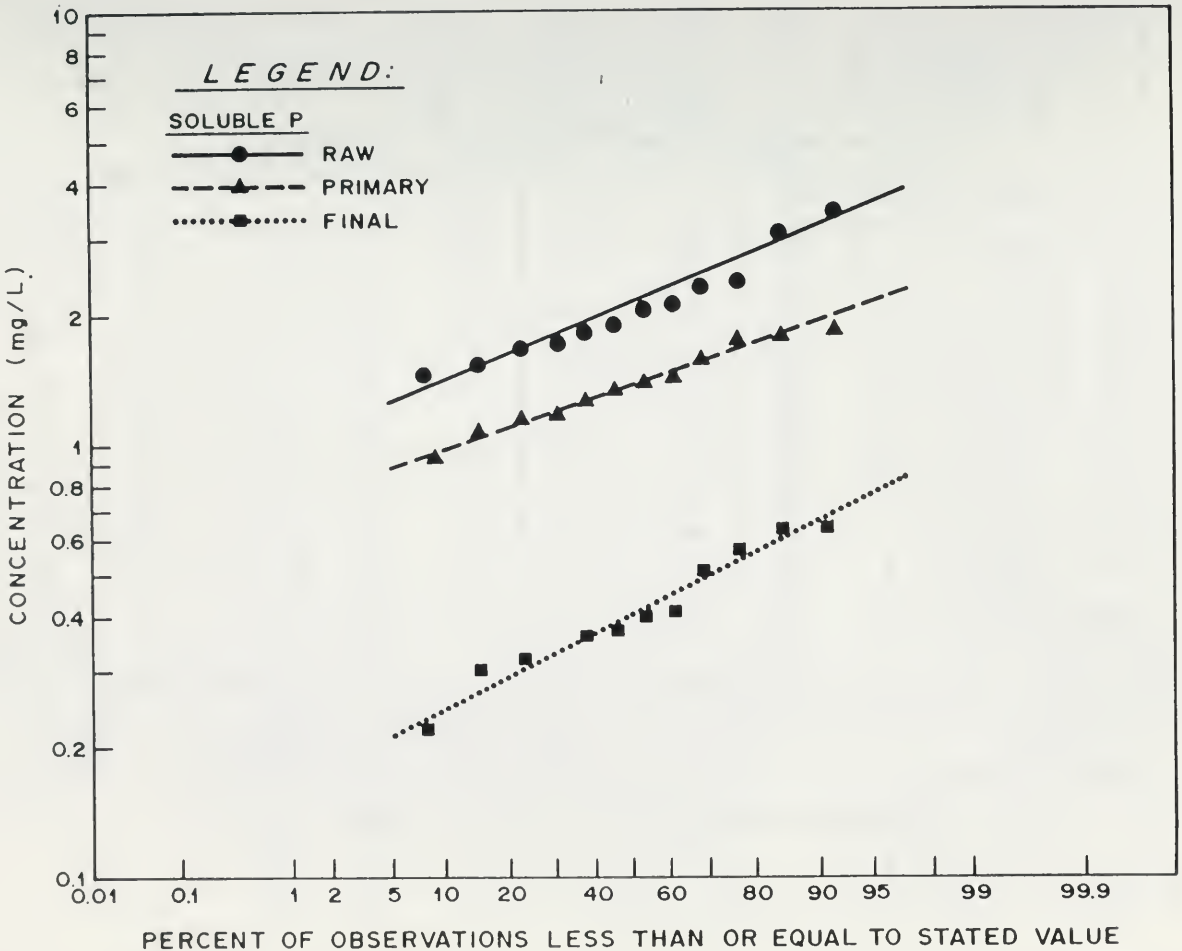


FIGURE 2-2: PROBABILITY DISTRIBUTION OF SOLUBLE PHOSPHORUS DATA AT THE FERGUS WPCP

TABLE 2.6. SUMMARY OF KEY OPERATING PARAMETERS FOR FERGUS WPCP

DATE	FLOW ($10^3 m^3/d$)		CLARIFIER LOAD ($m^3/m^2 \cdot d$)		Fe^{2+} DOSAGE (mg/L)	PRIM. EFF. SOL. P (mg/L)	Fe:P RATIO*		EFFLUENT QUALITY (mg/L)			
	AVERAGE	MAXIMUM	AVERAGE	MAXIMUM			WEIGHT	MOLAR	TSS	TP	SOL.P	PART.P
18/6	3.92	4.82	17.2	21.2	2.96	1.80	1.64	0.91	10	0.57	0.51	0.06
19/6	3.89	4.78	17.1	21.0	2.98	1.17	2.54	1.41	12	0.68	0.64	0.04
23/6	4.33	6.92	19.1	30.4	3.78	1.42	2.66	1.48	9	0.48	0.41	0.07
24/6	3.95	5.01	17.4	22.0	4.15	1.82	2.28	1.27	7	0.26	0.22	0.04
25/6	3.82	4.78	16.8	21.0	4.28	1.54	2.78	1.54	6	0.37	0.30	0.07
26/6	3.81	5.05	16.8	22.2	4.30	1.77	2.43	1.34	10	0.50	0.32	0.18
3/7	3.54	4.46	15.6	19.6	7.05	1.28	5.51	3.06	16	0.53	0.37	0.16
4/7	3.40	4.46	15.0	19.6	7.34	1.33	5.52	3.06	16	0.48	0.32	0.16
7/7	3.55	4.82	15.6	21.2	4.60	1.40	3.29	1.82	33	0.91	0.63	0.28
8/7	3.47	4.78	15.3	21.0	4.71	0.94	5.01	2.78	14	1.03	0.57	0.46
9/7	3.30	4.10	14.5	18.0	4.95	1.15	4.30	2.39	5	0.62	0.40	0.22
10/7	3.40	4.60	15.0	20.2	4.81	1.08	4.45	2.46	--	0.59	0.36	0.23
AVERAGE	3.70	4.88	16.3	21.5	4.66	1.39	3.17	1.76	12.1	0.59	0.42	0.17

*Based on primary effluent soluble P concentrations

The soluble phosphorus concentrations in the effluent from primary treatment was low, averaging 1.39 mg/L and not found to exceed 1.8 mg/L. The iron dosage added for precipitation was 4.7 mg/L, resulting in a molar ratio of iron to soluble phosphorus of 1.76. Comparing this to the Fe:P stochiometric requirement of 1 shows that a sufficient dosage of ferrous was being added, resulting in low effluent soluble phosphorus concentrations, averaging 0.42 mg/L. It should be noted that plant staff aim to achieve effluent phosphorus concentrations of about 0.6 mg/L. The chemical dosage rate is adjusted daily based on daily on-site analysis of effluent phosphorus in an 8 a.m. grab sample.

2.3 Conclusions of Fergus WPCP Monitoring Program

The monitoring program at Fergus WPCP involved collection of 24-hour composite samples of influent, primary effluent and final effluent on twelve days over a 24 day period. The results confirmed the historical data in terms of flows, and influent and effluent concentrations of BOD_5 and total phosphorus. Relatively high influent suspended solids and low effluent suspended solids found during the monitoring period may be a result of the different sampling methodologies used during this study and used historically.

The major factors contributing to the efficient phosphorus removal achieved at Fergus WPCP were:

i) sufficient iron dosage resulting in low effluent soluble phosphorus concentrations; and,

ii) good sludge settleability and low secondary clarifier surface loading resulting in low effluent particulate phosphorus concentrations.

3.0 MIDLAND WATER POLLUTION CONTROL PLANT

3.1 Plant Description and Historical Performance

3.1.1 Plant Description

The Midland WPCP is operated by the Town of Midland, and serves a population of 12,000 (1985). Approximately 80 percent of the flow to the plant is domestic and 20 percent results from local industries. In September 1981, the plant was expanded from a primary plant to a conventional activated sludge plant designed to handle an average daily flow of 13,638 m^3/d. Figure 3.1 presents a schematic of the treatment plant. Key design parameters are summarized in Table 3.1.

Raw sewage is pumped into the plant from four off-site pumping stations. Flow is treated for grit removal by a detritor and is then divided for treatment in two parallel round primary clarifiers. Each clarifier is 14.5 m in diameter and has a side wall depth of 1.7 m, providing a surface area of 165 m^2 and a volume of 454 m^3. Waste activated sludge from the biological system is co-thickened with primary sludge in the clarifiers.

Following primary treatment, the total flow enters the aeration system consisting of six completely mixed mechanically aerated cells in series. Only four cells have been in use since the plant expansion in 1981. Each cell is 500 m^3, resulting in an aeration tank liquid volume of 2000 m^3 in use (total available 3000 m^3). Ferric chloride is added for phosphorus removal on a continuous basis to the fourth cell of the aeration tank. The chemical feed rate is occasionally adjusted manually.

After aeration, mixed liquor enters two parallel round secondary clarifiers for sedimentation. Each clarifier has a diameter of 29.7 m and a 3.05 m side wall depth, providing a surface area of 694 m^2 and a volume of 2,118 m^3. Return activated sludge is pumped to the front end of the aeration system and waste sludge from the return line enters the primary clarifiers for thickening. The total secondary clarifier effluent enters a chlorine contact chamber with total volume of 427 m^3. Chlorinated effluent is discharged to Midland Bay.

Sludge from the primary clarifiers is digested in a two stage anaerobic system. Both the primary digester and secondary digester provide volumes of 454 m^3. Methane gas produced in the anaerobic process is used in

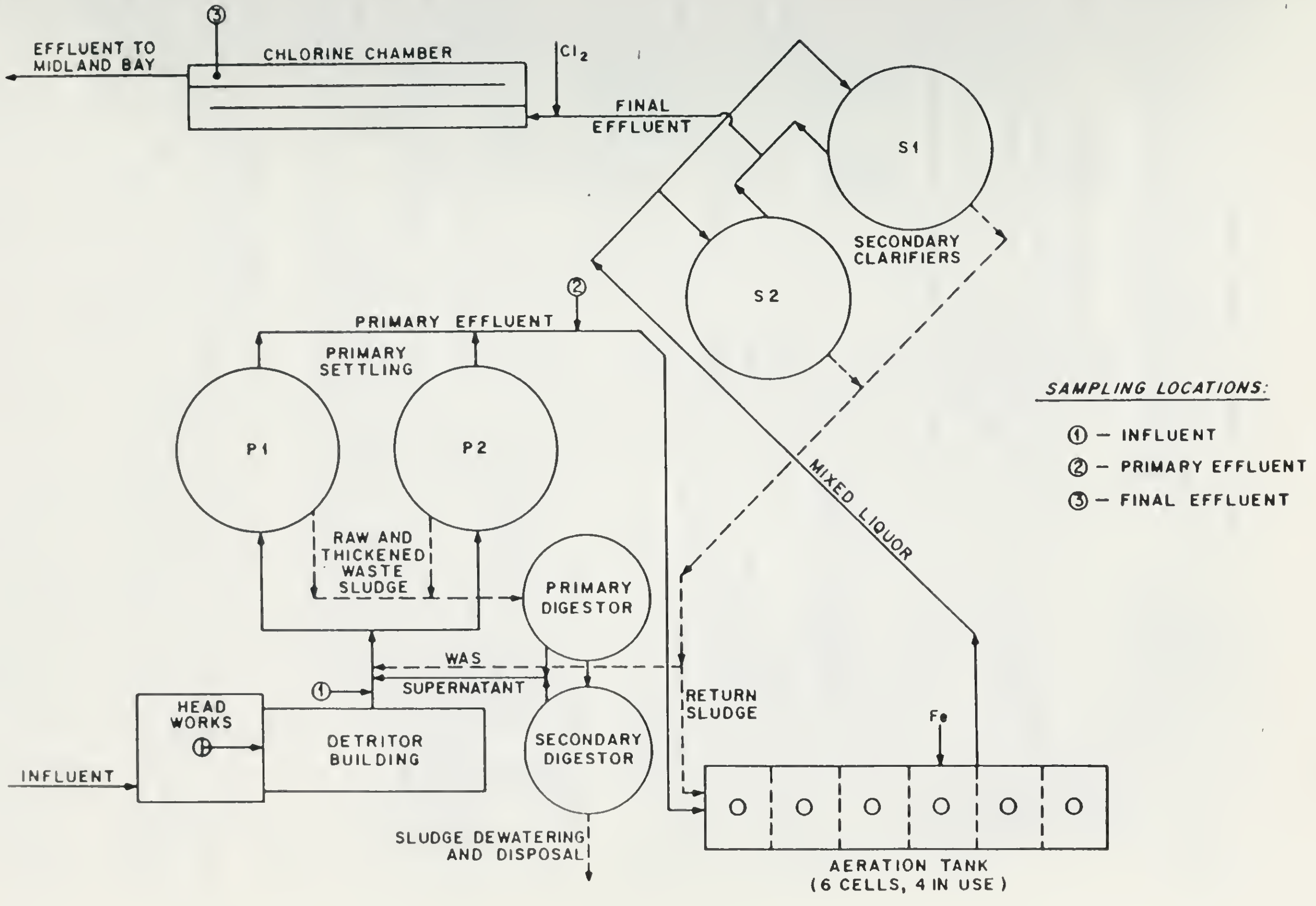


FIGURE 3-1: SCHEMATIC OF MIDLAND WPCP

TABLE 3.1: DESIGN SUMMARY - MIDLAND WPCP

DESIGN CRITERIA	DESIGN VALUE	OPERATING LEVEL *
Flow (m^3/d)		
Average Daily	13,638	9,250
Peak Day	--	est. 22,000
BOD Loading (kg/d)	3,069	700
Sewer Collection System	60% Combined	--
BYPASS	No Bypass	--
Primary Clarification		
HRT (Hours)	1.6	2.3
Avg Surface Load (m^3/m^2.d)	41.4	28.1
Peak Surface Load (m^3/m^2.d)		66.8
Aeration System**		
HRT (Hours)	3.5	5.2
BOD Load (kg/m^3.d)***	0.92	0.21
Return Sludge Rate (%)	--	75
Phosphorus Removal		
Chemical	$FeCl_3$	--
Average Dosage (mg Fe/L)	--	7.3 mg/L (1984), 5.2 mg/L (1985)
Secondary Clarification		
HRT (Hours)	7.5	11.0
AVG. Surface Load (m^3/m^2.d)	9.82	6.66
Peak Surface Load (m^3/m^2.d)	--	15.84
Chlorination		
HRT @ Peak Flow (min)	--	28.0

* Based on 1981-1985 Historical Data
** Based on 4 aeration cells in use.
*** At 40% primary clarifier BOD_5 removal.

the boiler at Midland WPCP. Digested sludge is dewatered by means of a multi-stage belt filter press and the dewatered sludge cake is hauled away for final disposal at a municipal landfill.

3.1.2 Historical Performance

Table 3.2 summarizes the annual performance of the Midland WPCP for the years 1981 to 1985. Since the plant expanded to secondary treatment in 1981, consistently high effluent quality has been achieved. Average effluent concentrations for 1982 to 1985 were 8.2 mg/L BOD_5, 6.3 mg/L for TSS and 0.48 mg/L total phosphorus. Influent strength, with the exception of phosphorus, has remained relatively steady since 1981, with average concentrations of 75.6 mg/L BOD_5 and 175 mg/L suspended solids. An extremely high influent concentration for total phosphorus was reported in 1981 (30.1 mg/L); however, 1982 to 1985 phosphorus concentrations were fairly steady, averaging 5.0 mg/L). A local industry discharged high concentrations of phosphorus as a result of phosphoric acid usage previous to 1982; this practice was discontinued in 1982 resulting in a significant decrease in raw wastewater total phosphorus content.

The monthly average effluent quality data for 1984 and 1985 are presented in Table 3.3. With the exception of two months in 1984, most of monthly averages were based on less than five samples per month. No data was reported for 1 month in each year. The monthly average BOD_5 concentrations were less than 15 mg/L for all but three months in 1984. Effluent suspended solids concentrations were found to be less than 15 mg/L for all months in 1984 and 1985. Effluent phosphorus concentrations were less than 1 mg/L for all but one month in 1984.

3.1.3 Monitoring Program

The Midland WPCP was sampled on 12 days in the one month period between 24 June to 24 July, 1986. Samples were not collected on weekends or during local industry shutdowns so that plant flows and influent strengths were typical of normal operation.

Sampling locations were identified in Figure 3.1. Twenty-four hour composite samples of raw wastewater after grit removal and primary effluent were collected. Flow proportioned 24-hour composite samples of secondary ef-

TABLE 3.2. ANNUAL AVERAGE PERFORMANCE OF MIDLAND WPCP

PARAMETER	YEAR					5 YEAR AVERAGE 81 - 85
	1981	1982	1983	1984	1985	
Avg. Daily Flow (1000·m^3/d)	8.70	8.41	9.00	9.24	10.91	9.25
BOD$_5$ - Influent (mg/L)	78.2	82.0	81.4	68.3	67.7	75.6
BOD$_5$ - Effluent (mg/L)	33.2	7.2	8.7	13.9	3.0	8.2*
TSS - Influent (mg/L)	211.2	190.0	169.3	170.0	131.9	174.6
TSS - Effluent (mg/L)	36.9	4.2	7.3	7.4	6.4	6.3*
Total P - Influent (mg/L)	30.1	6.00	4.77	4.91	4.50	5.00
Total P - Effluent (mg/L)	11.7	0.46	0.32	0.56	0.57	0.48*

* Based on 1982 to 1985 data only.

TABLE 3.3 MONTHLY AVERAGE PERFORMANCE OF MIDLAND WPCP

Year	Month	Effluent BOD_5 (mg/L)	n BOD	Effluent TSS (mg/L)	n TSS	Effluent TP (mg/L)	n TP
1984	Jan.	6.1	1	11.5	1	0.30	1
	Feb.	11.0	1	7.7	1	0.25	1
	Mar.	--	-	--	-	--	-
	Apr.	9.0	1	14.0	1	0.53	1
	May	7.8	2	7.3	2	0.72	2
	June	2.8	4	8.0	4	0.45	4
	July	15.6	3	4.6	3	0.42	3
	Aug.	43.8	5	5.9	5	0.53	5
	Sept.	23.8	3	4.8	3	0.65	3
	Oct.	11.1	9	5.1	9	0.33	8
	Nov.	12.6	5	5.9	4	0.91	4
	Dec.	9.0	3	6.6	3	1.12	3
1985	Jan.	2.4	1	7.9	1	0.62	1
	Feb.	1.9	1	5.1	2	--	-
	Mar.	2.9	2	9.3	2	0.47	1
	Apr.	2.3	2	6.2	2	0.86	1
	May	3.2	2	5.7	2	0.69	1
	June	4.8	2	6.2	2	0.80	2
	July	--	-	--	-	0.60	-
	Aug.	1.5	3	4.2	3	0.49	3
	Sept.	1.3	1	5.9	1	0.55	1
	Oct.	2.4	2	4.9	2	0.31	2
	Nov.	2.6	2	6.4	2	0.37	2
	Dec.	8.0	2	9.2	2	0.55	2

n - number of samples

fluent (after chlorination) were collected. Mixed liquor suspended solids analyses conducted on site by plant staff at Midland WPCP were recorded, but occasional grab samples of return sludge were taken to allow SRT calculations to be carried out.

3.2 Results of Sampling Program

Table 3.4 presents a summary of operating data for the twelve days the plant was sampled. The average daily flow for these days was 10,350 m^3/d or 75.9 percent of design flow. The instantaneous peak flow varied from 16,000 to 23,000 m^3/d. Despite heavy rainfall during this period, the flows were relatively invariable and were comparable to the annual average 1985 flow of 10,910 m^3/day.

A steady mixed liquor concentration in the aeration tank averaged 3,430 mg/L for the twelve days. An average of 153 m^3/d of sludge was wasted, resulting in a solids retention time of 5.2 days. Complete nitrification has historically not been achieved by the plant as shown by an annual average effluent ammonia concentration of 9.0 mg/L reported in 1985.

Ferric chloride was added continuously to the fourth cell of the aeration tank. Chemical flow rates were adjusted occasionally by plant staff and usage was calculated on a daily basis from the increment in the liquid level in the ferric chloride storage tank. One grab sample of ferric chloride analyzed for iron concentration (12.5%) in the chemical tank used in the sampling period was comparable to the concentration reported by the chemical distributor of 12.7 percent. The weight of iron and resulting dosages were based on daily chemical volume utilization and average daily flows. An average of 38 kg Fe^{3+}/d was used over the days sampled, resulting in an average iron dosage of 3.7 mg/L.

The results of the monitoring program are summarized in Table 3.5. The raw wastewater strength in terms of BOD_5 was low compared to historical data, averaging only 55.1 mg/L. Influent suspended solids concentrations, averaging 164 mg/L, were comparable to historical data despite the fact that there were three days on which the concentration was less than 90 mg/L. The low average BOD_5 and occasionally low suspended solids concentrations were probably a result of stormwater dilution in the combined sewer system, since low values occurred on the days that it rained. Influent phosphorus concentration averaging 5.8 mg/L were comparable to the historical average.

TABLE 3.4. SUMMARY OF MIDLAND WPCP OPERATING CONDITIONS DURING SAMPLING PERIOD

DATE (1986)	FLOW ($10^3 m^3/d$)		MLSS (mg/L)	MLVSS (%)	RAS (mg/L)	WAS (m^3)	Fe^{3+} (kg)	Fe DOSAGE (mg/L)	SRT (days)	COMMENTS
	TOTAL	MAX.								
24/6	11.38	20	3,148			225	45	3.95	↑	Rain
25/6	10.62	22	3,226	57.3	7,923	225	26	2.45		
3/7	10.23	19	3,316			167	25	2.44		
4/7	10.60	17	3,121	48.8	9,680	209	20	1.89		
8/7	10.93	22	3,418			216	43	3.93		Rain
9/7	10.65	16	3,485			84	43	4.04	5.2	
10/7	10.65	23	3,638			225	43	4.04		Rain
11/7	10.88	17	3,346	54.6	8,150	35	43	3.95		
15/7	10.11	20	3,635			79	43	4.26		
16/7	10.72	19	3,687	58.2	8,260	204	43	4.01		
22/7	8.85	21	3,366			0	43	4.86		Rain
23/7	8.60	21	3,761			173	43	5.00	↓	Rain
AVG.	10.35	19.8	3,429		8,111	153	38	3.7	5.2	

TABLE 3.5. SUMMARY OF PERFORMANCE MONITORING DATA FOR MIDLAND WPCP

DATE	STREAM	CONCENTRATION			
		BOD_5	TSS	Total P	Sol. P
24/6	Raw	40	190	4.2	1.34
	Primary Effluent	-	-	2.24	1.57
	Final Effluent	2.5	6	0.63	0.52
25/6	Raw	49	130	3.2	1.58
	Primary Effluent	-	-	3.16	1.34
	Final Effluent	3.1	6	0.60	0.52
3/7	Raw	54	290	5.7	3.11
	Primary Effluent	-	-	2.02	1.95
	Final Effluent	1.0	12	0.69	0.52
4/7	Raw	54	290	5.7	3.11
	Primary Effluent	-	-	2.02	1.95
	Final Effluent	1.1	10	-	-
8/7	Raw	54	120	3.5	1.90
	Primary Effluent	-	-	4.25	1.75
	Final Effluent	2.6	9	0.79	0.63
9/7	Raw	72	170	5.9	2.20
	Primary Effluent	-	-	2.75	1.48
	Final Effluent	2.2	8	0.69	0.52
10/7	Raw	9.7	25	5.3	2.47
	Primary Effluent	-	-	3.70	2.36
	Final Effluent	5.4	7.5	0.59	0.58
11/7	Raw	49.3	180	8.0	4.78
	Primary Effluent	-	-	4.12	2.15
	Final Effluent	2.9	7	0.79	0.68
15/7	Raw	66	190	5.0	1.86
	Primary Effluent	-	-	2.40	0.45
	Final Effluent	3.1	6	0.55	0.42
16/7	Raw	59	200	11.7	1.2
	Primary Effluent	-	-	2.80	1.27
	Final Effluent	1.7	4	0.53	0.45
22/7	Raw	59	90	6.5	4.6
	Primary Effluent	-	-	4.19	1.70
	Final Effluent	3.0	3	0.89	0.53
23/7	Raw	95	90	4.6	2.7
	Primary Effluent	-	-	2.50	2.00
	Final Effluent	3.0	3	0.80	0.66
Averages	Raw	55.1	164	5.78	2.57
	Primary Effluent	-	-	3.01	1.66
	Final Effluent	2.6	6.2	0.69	0.54
Standard Dev.	Raw	20.0	78.7	2.28	1.17
	Primary Effluent	-	-	0.85	0.50
	Final Effluent	1.1	3.3	0.12	0.09

Average effluent concentrations found for the days monitored were 2.6 mg/L BOD_5, 6.2 mg/L suspended solids and 0.54 mg/L total phosphorus. Effluent quality in terms of BOD_5 and suspended solids was better than found in the historical data (1982 - 1985), but was comparable to the 1985 average. Effluent phosphorus concentration were similar to the historical average.

The excessive rainfall during the study period has been suggested as one factor in the discrepancies between historical data and monitoring data. Another factor may be the differences in sampling frequencies. Although both historical data and the present monitoring data were based on 24-hour composite samples, the present study provided a much larger and more intensive data base. The historical data base was typically based on two samples per month. Since there was some variability noted in influent concentrations of BOD_5 and suspended solids in this study, two samples per month may not have been representative of the actual monthly concentrations.

Figure 3.2 presents probability distributions for total phosphorus in raw and final effluent and soluble phosphorus in raw, primary effluent and final effluent. It can be observed that despite the high variability (indicated by the slope of the probability line) in influent total and soluble phosphorus, effluent total and soluble phosphorus concentrations show relatively little variability. By extrapolation, the 95 percent probability concentration (95 percent probability of a concentration less than or equal to) for influent total phosphorus is 12 mg/L and for effluent total phosphorus is 0.92 mg/L.

Key operating parameters affecting phosphorus removal at the Midland WPCP are summarized in Table 3.6. The average flow during the period was 10,350 m^3/d or 76 percent of design capacity. The resulting secondary clarifier surface load was 7.5 $m^3/m^2 \cdot d$. The extremely low clarifier surface loading and the good sludge settleability observed at the plant provided excellent removal of suspended solids. The average suspended solids concentration found in the effluent was 6.2 mg/L, which caused very low effluent particulate phosphorus concentrations averaging 0.16 mg/L.

The molar ratio of iron to primary clarifier soluble phosphorus averaged 1.53. Since the stociometric requirement of Fe:P is 1, it can be concluded that there was a sufficient reserve of iron in the aeration system

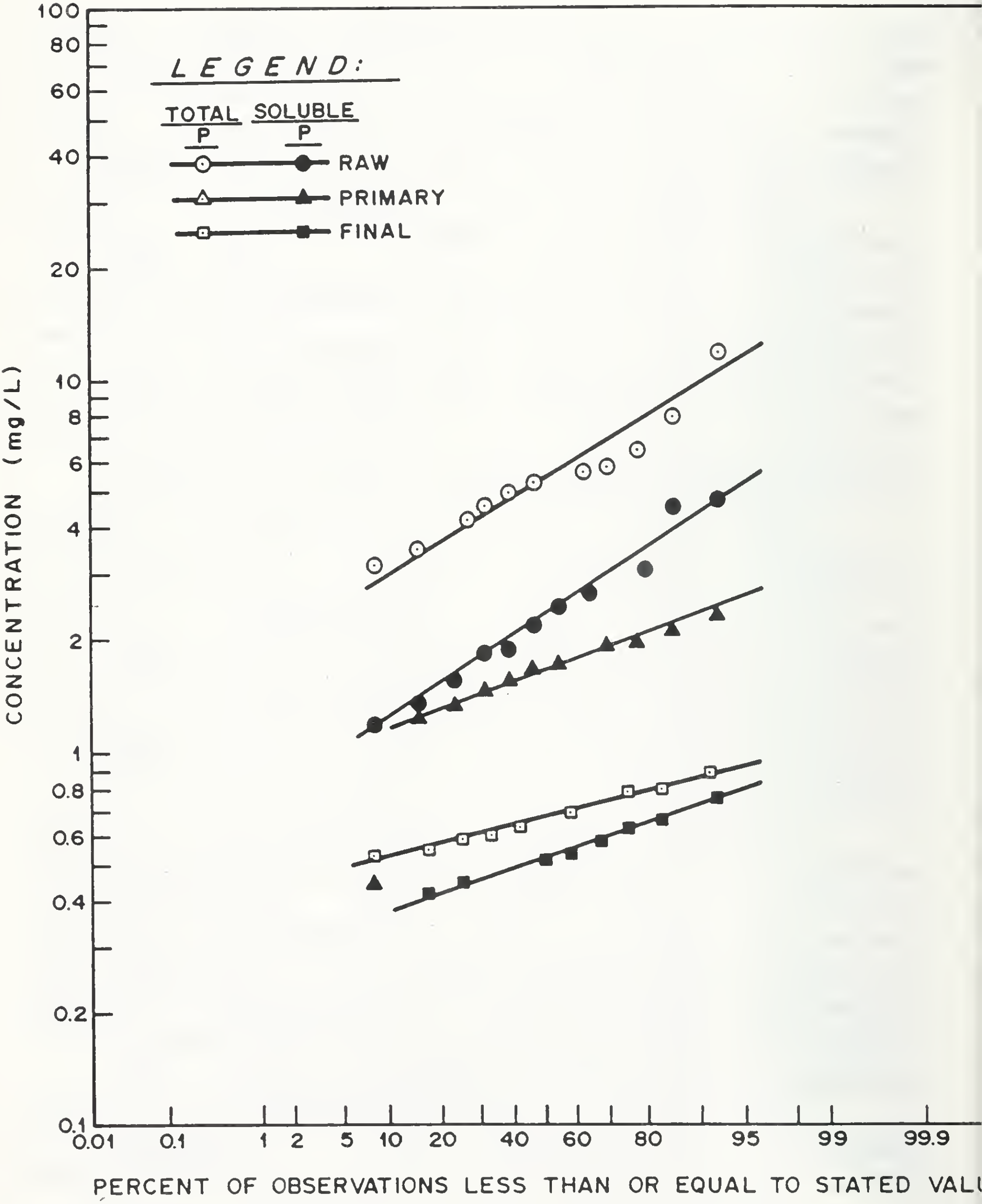


FIGURE 3-2: PROBABILITY DISTRIBUTIONS FOR PHOSPHOR
DATA AT THE MIDLAND WPCP

TABLE 3.6. SUMMARY OF KEY OPERATING PARAMETERS FOR MIDLAND WPCP

DATE	FLOW ($10^3 m^3/d$)		CLARIFIER LOAD ($m^3/m^2 \cdot d$)		Fe^{3+} DOSAGE (mg/L)	PRIM. CLAR. SOL. P (mg/L)	Fe:P RATIO*		EFFLUENT QUALITY (mg/L)			
	AVERAGE	PEAK	AVERAGE	PEAK			WEIGHT	MOLAR	TSS	TP	SOL.P	PART.P
24/6	11.38	20	8.19	14.4	3.95	1.57	2.52	1.40	6	0.63	0.42	0.21
25/6	10.62	22	7.65	15.84	2.45	1.34	1.83	1.01	6	0.60	0.52	0.08
3/7	10.23	19	7.36	13.68	2.44	1.95	1.25	0.69	12	0.69	0.52	0.17
4/7	10.60	17	7.63	12.24	1.89	1.95	0.97	0.54	10	--	--	--
8/7	10.93	22	7.87	15.84	3.93	1.75	2.25	1.25	9	0.79	0.63	0.14
9/7	10.65	16	7.67	11.52	4.04	1.48	2.73	1.51	8	0.69	0.52	0.17
10/7	10.65	23	7.67	16.56	4.04	2.36	1.71	0.95	7	0.59	0.58	0.01
11/7	10.88	17	7.83	12.24	3.95	2.15	1.84	1.02	7	0.79	0.68	0.11
15/7	10.11	20	7.28	15.12	4.26	0.45	9.47	5.25	6	0.55	0.42	0.13
16/7	10.72	19	7.72	13.68	4.01	1.27	3.16	1.75	4	0.53	0.45	0.08
22/7	8.85	21	6.38	15.12	4.86	1.70	2.86	1.59	3	0.89	0.53	0.36
23/7	8.60	21	6.19	15.12	5.00	2.00	2.50	1.39	3	0.80	0.66	0.26
AVERAGE	10.35	19.8	7.45	14.3	3.70	1.66	2.78	1.53	6.2	0.69	0.54	0.16

*Based on primary effluent soluble phosphorus concentration.

to buffer higher concentrations and maintain low phosphorus levels in the effluent. The effluent soluble phosphorus concentration was found to be steady, ranging from 0.42 to 0.66 mg/L for the twelve days.

3.3 Conclusions of the Midland WPCP Monitoring Program

The monitoring program at Midland WPCP involved collection of 24-hour composite samples of influent, primary effluent and final effluent on twelve days in a one month period. The results confirmed the historical data in terms of flows, and influent and effluent suspended solids and phosphorus concentrations. The relatively low influent BOD_5 concentrations were comparable to the 1984 and 1985 annual averages but were lower than the five year (1981 - 1985) average. This could imply that the trend since 1985 was lower influent BOD_5 strength, possibly due to increased sewer infiltration. The lower effluent BOD_5 concentration found for this study was comparable to the 1985 average, implying improved BOD_5 removal performance since 1984.

The major factor contributing to the effluent phosphorus removal efficiency at Midland WPCP was an extremely low secondary clarifier surface loading, resulting in very efficient suspended solids removal and low particulate phosphorus concentrations. Chemical dosage, at an average molar ratio (Fe:P) of 1.5 based on primary effluent soluble phosphorus, was adequate to maintain secondary effluent soluble phosphorus concentrations in the 0.4 to 0.7 range.

4.0 COLLINGWOOD WATER POLLUTION CONTROL PLANT

4.1 Plant Description and Historical Performance

4.1.1 Plant Description

The Collingwood WPCP serves a population of 11,500 in the Town of Collingwood. Approximately one half of the flow to the plant is contributed by local industries, including 3,600 m^3/d from a glass manufacturing plant and 1,750 m^3/d from a starch industry. The plant was expanded from a primary facility in 1981 to a conventional activated sludge plant with flow capacity of 24,548 m^3/day. Figure 4.1 presents a flow schematic of the plant. Key design parameters are presented in Table 4.1.

Raw sewage passes through a bar screen to the raw sewage pump station, where the flow is lifted to the inlet works. A flow recorder measures influent flows.

The flow is treated in two parallel aerated grit tanks and two barminutors. Primary clarification following grit removal takes place in three parallel rectangular clarifiers, each with a surface area of 177 m^2 and a depth of 3.5 m, providing a volume of 629 m^3. Primary sludge is pumped to the sludge digesters.

Biological treatment of the flow takes place in two parallel aeration tanks, each consisting of three cells. Each cell is equipped with a 40 HP mechanical surface aerator. Each tank provides a volume of 2915 m^3 for aeration.

Sedimentation takes places in two rectangular clarifiers, each with surface areas of 746 m^2 and 3.7 m side wall depth, providing a volume of 2760 m^3. Collectors scrape the settled sludge from the bottom of the tanks to hoppers. The secondary sludge is removed from the hoppers through adjustable valves by hydrostatic pressure, and returned by two Archemedian-type screw pumps to the aeration tanks.

Sludge wasted from the return line is thickened in a dissolved air flotation thickener and then digested in a two stage anaerobic digestion process. Two primary digesters and two secondary digesters are available for digestion. Digested sludge is hauled away from the plant for land disposal and supernatant is returned to the front end of the plant.

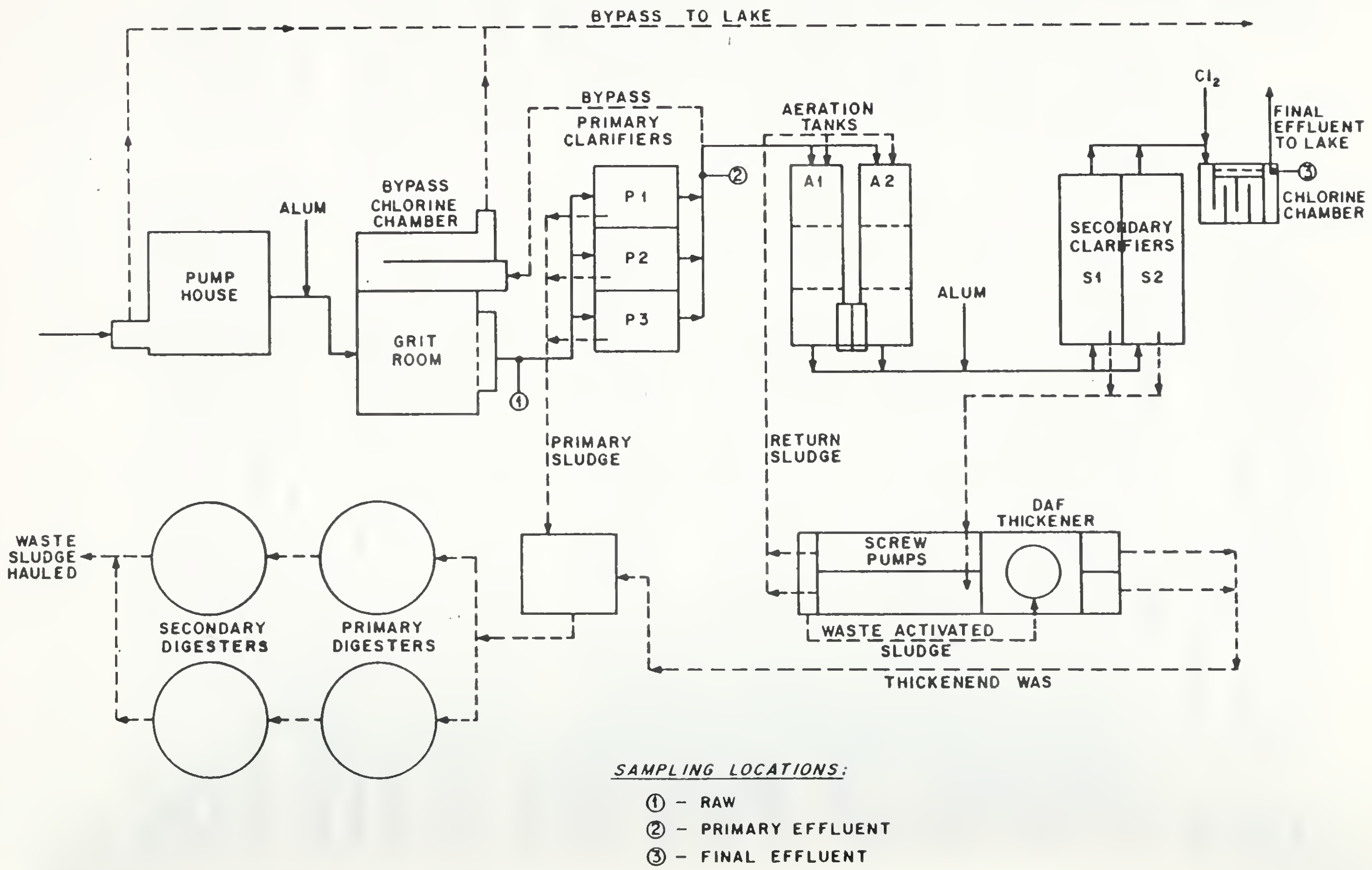

BYPASS TO LAKE
PUMP HOUSE
ALUM
BYPASS CHLORINE CHAMBER
GRIT ROOM
①
BYPASS PRIMARY CLARIFIERS
P 1
P 2
P 3
②
AERATION TANKS
A 1
A 2
ALUM
SECONDARY CLARIFIERS
S 1
S 2
Cl_2
FINAL EFFLUENT TO LAKE
③
CHLORINE CHAMBER
PRIMARY SLUDGE
RETURN SLUDGE
DAF THICKENER
SCREW PUMPS
WASTE ACTIVATED SLUDGE
THICKENEND WAS
WASTE SLUDGE HAULED
SECONDARY DIGESTERS
PRIMARY DIGESTERS
SAMPLING LOCATIONS:
① - RAW
② - PRIMARY EFFLUENT
③ - FINAL EFFLUENT

TABLE 4.1 - DESIGN SUMMARY - COLLINGWOOD WPCP

DESIGN CRITERIA	DESIGN VALUE	OPERATING LEVEL*
Flow (m^3/d)		
Average Daily	24,548	16,830
Peak Day	86,374	Est 31,822
BOD Loading (kg/d)	4,910	2,864
Sewer Collection System	10% Combined Flow	
Bypass - Point	Influent Overflow	-
Frequency	-	Never
Discharge Point	Before Chlorination	-
Primary Clarification		
HRT (hours)	1.8	2.6
Avg. Surface Load ($m^3/m^2 \cdot d$)	42.2	28.9
Peak Surface Load ($m^3/m^2 \cdot d$)	162.5	59.9
Aeration System		
HRT (hours)	5.8	8.46
BOD Load ($kg/m^3 \cdot d$)	0.64	0.29
Return Sludge Rate (%)	-	40
Phosphorus Removal		
Chemical	Alum	
Average Dosage (mg Al/L)	-	1984=2.9, 1985=3.9
Secondary Clarification		
HRT (hours)	5.4	3.7
Avg. Surface Loading ($m^3/m^2 \cdot d$)	16.5	11.3
Peak Surface Loading ($m^3/m^2 \cdot d$)	58.1	21.4
Chlorination		
HRT @ Peak Flow (min)	8.5	23.1

*Based on 1981-1985 Historical Data

**At 40% primary clarifier BOD_5 removal

Secondary effluent is chlorinated in a 1022 m^3 chlorine contact chamber before discharge into the Nottawasaga Bay.

Phosphorus removal from the wastewater takes place by continuous addition of alum. Approximately 40 percent of the alum dosage is added to the force main directly before treatment in the aerated grit tanks. The remaining 60 percent is added to the mixed liquor prior to secondary clarification. Chemical addition rates at both points can be varied in proportion to plant flow.

4.1.2 Historical Performance

Table 4.2 summarizes the annual performance of the Collingwood WPCP for the years 1981 to 1985.

Influent strength for the five years has been moderate, with an average BOD_5 of 170 mg/L, an average suspended solids of 150 mg/L and average influent total phosphorus of 7.76 mg/L. The annual average influent total phosphorus increased significantly from less than 6.5 mg/L for 1981 to 1983 to greater than 10.2 mg/L for 1984 and 1985.

After the expansion to secondary treatment in 1981, good effluent quality in terms of BOD_5 and suspended solids has been achieved for all years (1982 to 1985). Four year average effluent concentrations were 9.2 mg/L BOD_5 and 13.3 mg/L suspended solids. Effluent total phosphorus concentrations were consistently above 1 mg/L for all years except 1982, resulting in a four year average of 1.42 mg/L.

Table 4.3 presents the monthly average effluent quality data for 1984 and 1985. BOD_5 concentrations were found to be less than the MOE design criteria of 15 mg/L for all except two months in 1984, and did not exceed the MOE effluent requirement of 25 mg/L in any month of the two year period. Effluent suspended solids concentrations ranged from 5.5 mg/L to 39 mg/L. With the exception of 5 months, monthly average effluent suspended solids were less than or equal to the MOE design criterion of 15 mg/L and exceeded effluent guidelines of 25 mg/L for two of these months. Phosphorus concentrations in the effluent ranged from 0.62 to 2.5 mg/L. In total, only four months in the two year period were reported to have effluent total phosphorus concentrations less than 1 mg/L.

TABLE 4.2 - ANNUAL AVERAGE PERFORMANCE OF COLLINGWOOD WPCP

PARAMETER	YEAR					5 YEAR AVERAGE 1981 - 85
	1981	1982	1983	1984	1985	
Avg. Daily Flow (1000 m^3/day)	15.91	15.28	17.86	17.38	18.54	16.83
BOD_5 - Influent (mg/L) BOD_5 - Effluent (mg/L)	- 70.0	193.0 15.0	200.0 8.0	134.3 7.9	163.3 5.8	170.2 9.2*
TSS - Influent (mg/L) TSS - Effluent (mg/L)	112.0 42.0	192.0 15.0	154.0 10.2	165.7 15.3	131.1 12.6	150.9 13.3*
Total P - Influent (mg/L) Total P - Effluent (mg/L)	5.10 1.85	6.40 0.60	5.59 1.65	10.21 1.49	11.18 1.92	7.76 1.42*

* Only 1982-1985 included in average

4.3 - MONTHLY AVERAGE PERFORMANCE OF COLLINGWOOD WPCP

YEAR	MONTH	EFFLUENT BOD_5 (mg/L)	n BOD	EFFLUENT TSS (mg/L)	n TSS	EFFLUENT TP (mg/L)	n TP
1984	Jan.	6.6	1	14.0	1	0.80	1
	Feb.	4.4	1	8.7	1	2.66	1
	Mar.	6.4	1	11.0	1	1.37	1
	Apr.	1.5	1	39.0	1	1.30	1
	May	10.4	1	23.6	1	3.20	1
	Jun.	3.5	1	9.1	1	0.62	1
	Jul.	23.0	2	-	-	1.40	1
	Aug.	20.0	2	23.0	-	0.60	1
	Sep.	2.2	1	5.5	1	1.08	1
	Oct.	5.0	1	18.0	1	1.20	1
	Nov.	7.0	2	8.0	2	-	-
	Dec.	5.2	1	8.0	1	2.20	1
1985	Jan.	3.5	3	9.0	4	2.57	2
	Feb.	4.5	4	10.1	5	2.11	3
	Mar.	5.0	3	5.5	2	1.40	1
	Apr.	7.0	2	16.0	2	1.40	1
	May	3.5	2	15.0	2	1.00	1
	Jun.	6.0	2	15.0	1	0.80	1
	Jul.	7.8	2	10.0	2	2.30	2
	Aug.	4.5	2	7.0	3	1.10	1
	Sep.	5.0	2	30.0	3	3.50	1
	Oct.	10.3	5	12.7	9	2.40	6
	Nov.	4.3	3	8.6	3	1.40	7
	Dec.	8.0	3	12.1	4	3.00	8

n - Number of samples

In terms of sampling frequency, all monthly average values were based on one or two samples per month until October 1985. After that time, more samples were taken and analyzed on-site to increase the number of monthly samples included in the average value. In 1986, at least five samples per week of influent and effluent suspended solids and total phosphorus have been analyzed on-site.

4.1.3 Sampling Program

The Collingwood WPCP was sampled eleven days in the 28 day period between 18 June and 15 July, 1986. Sampling locations were identified in Figure 4.1. Twenty-four hour composite samples of raw wastewater and primary effluent were collected. Flow proportioned 24-hour composite samples of secondary effluent after chlorination were collected. In addition, occasional grab samples of mixed liquor and return sludge were collected to allow SRT calculations to be completed.

4.2 - Results of Sampling Program

Table 4.4 presents the plant operating data for the eleven days that the Collingwood WPCP was monitored. Flows during the monitoring period averaged 17,440 m^3/day or 71 percent of design flow. This was not significantly different from the 1984 and 1985 annual average flows. Peak flows were less than the design peak, with the maximum peak flow during the 12 day period of 23,000 m^3/d or 37 percent of design peak capacity. Although peak flows are not documented as a normal practice at the plant, plant staff confirmed that daily flows are typically relatively constant.

The biological plant was operating in a stable mode, with high average mixed liquor concentrations of 5244 and 6844 mg/L for the two aeration tanks. Sludge was wasted at a constant rate of 229 m^3/day, with an average concentration of 1.48 percent as solids. The resulting solids retention time for the twelve days averaged 10.2 days.

Alum was added on a continual basis at the two locations stated. Although alum dosages were adjusted automatically based on measured plant flows, the resulting dosage did not correlate to the total flow indicating that there was a problem with the automatic dosage controller. Plant staff explained that the pumps were old and not performing accurately. The average aluminum dosage to the plant for the eleven days was 8.1 mg/L.

TABLE 4.4 - SUMMARY OF COLLINGWOOD OPERATING CONDITIONS ON DAYS SAMPLED

DATE (1986)	FLOW (19 m^3m^3/d)		BYPASS	MLSS (mg/L)		AVG. MLVSS (%)	RAS (%SOLIDS)	WAS (m^3)	ALUM* (kg)	Al $^{3+}$ DOSAGE (mg/L)	ESTIMATED SRT (days)	COMMENTS
	TOTAL	MAX		#1	#2							
18/6	16.99	23	no	5316	7812	51.3	1.55	229	1440	7.71	10.6	
19/6	18.38	22	no	4796	6568		1.49	229	1440	7.12	9.4	Rain
23/6	17.63	21	no	4696	5924		1.47	229	1920	9.90	9.0	Rain
25/6	17.60	26	no	4556	5548		1.08	229	1560	8.06	11.5	
26/6	17.47	23	no	4844	5676	62.1	1.39	229	1800	9.37	9.3	
2/7	16.99	22	no	5732	6284		1.39	229	940	5.03	10.6	
3/7	16.84	22	no	5220	6344		1.33	229	1645	8.88	10.7	
7/7	17.19	23	no	5316	7608	57.4	1.46	229	1125	5.95	10.9	
8/7	17.19	24	no	5976	8324		1.80	229	940	4.97	10.0	Rain
14/7	17.85	25	no	5452	8324		1.86	229	3290	16.76	9.1	Rain
15/7	17.70	22	no	5780	7292	58.6	1.45	229	960	4.93	11.4	
AVERAGE	17.44	23		5244	6844	57.3	1.48	229	1562	8.06	10.2	

*Total alum added to raw wastewater and mixed liquor

Table 4.5 presents the results of the monitoring program. Wastewater strength in terms of BOD_5 and suspended solids was comparable to the historical averages for 1981 to 1985. Influent concentrations for the twelve days sampled averaged 145 mg/L BOD_5 and 178 mg/L TSS. Influent concentrations of total phosphorus averaged 13.7 mg/L which was consistent with the high influent concentrations recorded in 1984 and 1985. Influent phosphorus concentrations have been typically high and variable, ranging from below 10 mg/L to above 50 mg/L, as reported by plant staff. Two local industries contributing high flows also use phosphorus in their processes. Trisodium phosphate used for glass washing is discharged from the glass plant in concentrations of up to 90 mg/L according to Collingwood WPCP staff. The starch industry uses phosphorus in various products, and phosphorus-bearing process wastewaters are discharged into municipal sewers for final treatment at the municipal plant.

Final effluent concentrations of BOD_5 and TSS averaged 1.7 mg/L and 7 mg/L respectively. These values were both notably lower than the historical average concentrations found for these parameters. However, the average effluent phosphorus concentration of 1.5 mg/L was not significantly different than the historical average. It should be noted that effluent phosphorus concentrations ranged from 0.28 mg/L to 2.9 mg/L, with concentrations less than 1 mg/L in only 45 percent of samples. The average total phosphorus concentration was made up of 73 percent soluble phosphorus.

At the Collingwood WPCP, influent historical data was based on twenty-four hour composite samples, taken in the same manner as for this study. This may explain the similarities found in influent strength found between the historical data and this study. However, effluent samples taken for the historical data have been either 8 hour manually composited or (8 a.m.) grab samples. These samples did not include the night flows (i.e 5 p.m. to 8 a.m.). The discrepancies found between the historical data and the data reported in the present study may be a result of the different sampling methodologies used.

Figure 4.2 presents probability plots of the influent and effluent total and soluble phosphorus concentrations, and the primary effluent soluble phosphorus concentrations recorded in this study. From the influent total phosphorus curve, it can be observed that for about 70 percent of the time concentrations were less than 13 mg/L, and about 30 percent of the time they

TABLE 4.5: SUMMARY OF PERFORMANCE MONITORING DATA FOR COLLINGWOOD WPCP

		CONCENTRATION (mg/L)			
DATE	STREAM	BOD_5	TSS	TOTAL P	SOLUBLE P
18 June	Raw	80	120	8.56	6.28
	Primary Effluent	-	-	2.84*	0.60*
	Final Effluent	1.7	6	-	-
19 June	Raw	140	110	10.96	10.0
	Primary Effluent	-	-	10.24	-
	Final Effluent	1.8	8	0.28	0.26
23 June	Raw	240	310	20.2	10.4
	Primary Effluent	-	-	8.34	5.73
	Final Effluent	1.8	6	0.33	0.26
25 June	Raw	150	340	23.0	13.0
	Primary Effluent	-	-	9.70	9.40
	Final Effluent	0.9	10	0.59	0.38
26 June	Raw	164	200	20.6	18.8
	Primary Effluent	-	-	-	-
	Final Effluent	1.1	10	2.06	1.58
2 July	Raw	112	160	10.9	10.5
	Primary Effluent	-	-	9.50	5.87
	Final Effluent	1.0	9	2.70	2.63
3 July	Raw	126	130	11.1	10.5
	Primary Effluent	-	-	8.60	8.28
	Final Effluent	0.8	9	2.90	1.73
7 July	Raw	207	210	12.5	10.5
	Primary Effluent	-	-	-	-
	Final Effluent	2.3	9	2.35	0.95
8 July	Raw	102	130	10.6	8.3
	Primary Effluent	-	-	8.90	6.3
	Final Effluent	2.6	7	2.72	2.5
14 July	Raw	122	120	10.5	8.5
	Primary Effluent	-	-	9.8	8.4
	Final Effluent	2.1	4	0.35	0.34
15 July	Raw	150	130	11.4	9.8
	Primary Effluent	-	-	10.1	8.6
	Final Effluent	3	3	0.48	0.35
AVERAGE	Raw	145	178	13.7	10.6
	Primary Effluent	-	-	8.8	6.6
	Final Effluent	1.7	7	1.5	1.10
STANDARD DEVIATIONS	Raw	46.2	78	5.0	3.2
	Primary Effluent	-	-	2.4	2.8
	Final Effluent	0.7	2	1.15	0.14

*Results may not be accurate due to precipitation of P in metal drum; switched to plastic on 19 June.

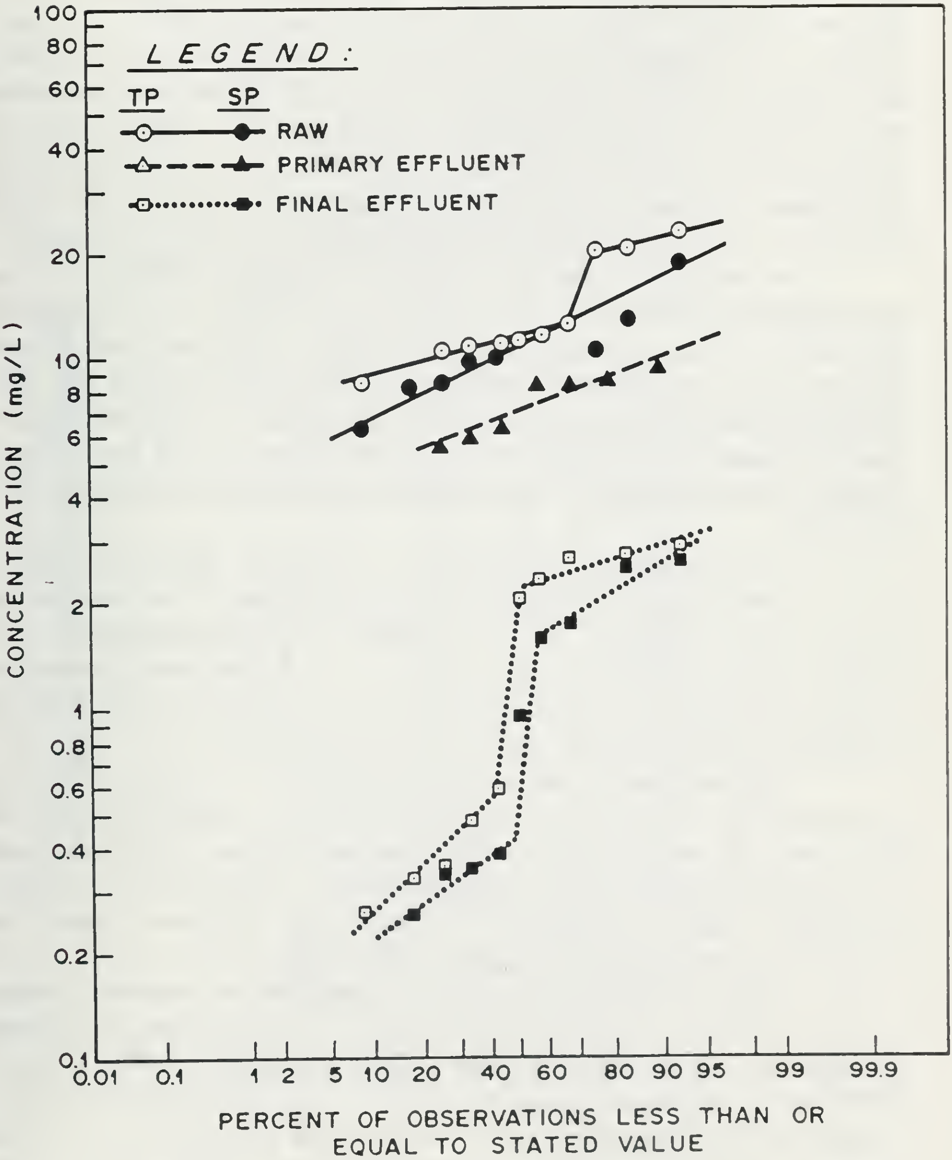


FIGURE 4-2: PROBABILITY DISTRIBUTIONS FOR PHOSPHORUS DATA AT THE COLLINGWOOD WPCP

were above 20 mg/L. There was some removal of phosphorus (average 36 percent) in the primary clarifier due to the alum addition upstream of primary treatment. The probability plot of effluent concentrations shows that there was a drastic increase in concentrations of effluent phosphorus corresponding to the increase in influent phosphorus concentrations, indicating that the plant could not handle the occasional high influent concentrations. Since the effluent total and soluble phosphorus curves were similar, it can be seen that high effluent concentrations consisted primarily of soluble phosphorus.

Key operating parameters affecting phosphorus removal at the Collingwood WPCP are summarized in Table 4.6. Clarifier hydraulic loadings were generally low, averaging only 11.7 $m^3/m^2 \cdot d$. The resulting effluent suspended solids concentrations averaging 7 mg/L provided evidence that good sludge settleability was occurring. This also resulted in a low average particulate phosphorus concentration of 0.28 mg/L, confirming that high effluent phosphorus concentrations are not associated with phosphorus in the particulate form.

The stochiometric ratio of Al:P required for phosphorus removal, is 1. In the primary clarifiers, there was an average of 19.3 percent removal of soluble phosphorus, with an average Al:P (soluble phosphorus) ratio of 0.38. More specifically, only about half of the available aluminum was used for precipitation of soluble phosphorus. There was sufficient mixing at the point of addition for the reaction to take place.

Alum was added to the secondary component of the plant at an average molar Al:P ratio of 0.77. The resulting average removal efficiency was 82.5 percent. A small amount of soluble phosphorus removal can be attributed to biological synthesis in the treatment process. However, it is indicated that nearly complete utilization of aluminum for phosphorus removal was accomplished in the secondary component of the plant.

Through the overall system, the average soluble phosphorus removal was 89.5 percent. The average molar ratio of Al:P was 0.94. It has been reported that for 95 percent removal of total phosphorus (TP), molar ratios of Al:P of 2.1 to 2.3 are typically required. The average Al:TP molar ratio recorded for this study was 0.59. At the influent phosphorus concentrations reported in this study, Al:TP ratios ranged from 0.35 for phosphorus concentrations greater than 20.0 mg/L to 0.86 for concentrations less than 11 mg/L.

TABLE 4.6: SUMMARY OF KEY OPERATING PARAMETERS FOR COLLINGWOOD WPCP

	FLOW ($10^3 m^3/d$)		CLARIFIER SURFACE LOADING ($m^3/m^2/d$)		PRIMARY CLARIFIERS						FINAL EFFLUENT						TOTAL SYSTEM				FINAL EFFLUENT (mg/L)	
					Al^{3+} Dosage	Al:P RATIO*		TP	SOLUBLE P	% REMOVAL SOLUBLE	Al^{3+} Dosage	Al:P RATIO*		TP	SOLUBLE P	% REMOVAL SOLUBLE	Al^{3+} Dosage	Al:P RATIO*		% REMOVAL SOLUBLE	TSS	PART.
DATE	AVG.	PEAK	AVG.	PEAK	(mg/L)	WT.	MOLAR	(mg/L)	(mg/L)	P	(mg/L)	WT.	MOLAR	(mg/L)	(mg/L)	P	(mg/L)	WT.	MOLAR	P		P
18 June	16.99	23	11.4	15.5	3.08	0.49	0.56	2.84	0.60	-	4.3	-	-	-	-	-	7.71	1.23	1.41	*	6	-
19	18.38	22	12.4	14.8	2.85	0.29	0.33	10.24	-	-	4.27	-	-	0.28	0.26	-	7.12	0.71	0.81	97.3	8	0.02
23	17.63	21	11.9	14.1	3.96	0.38	0.44	8.34	5.73	44.9	5.94	1.04	1.19	0.33	0.26	95.5	9.90	0.95	1.09	97.1	6	0.07
25	17.60	26	11.8	17.5	8.22	0.25	0.29	9.7	9.4	27.7	4.84	0.51	0.59	0.59	0.38	95.6	8.06	0.62	0.71	97.1	10	0.21
26	17.47	23	11.8	15.5	3.75	0.20	0.23	-	-	-	5.62	-	-	2.06	1.58	-	9.37	0.50	0.60	91.6	10	0.48
2 July	16.99	22	11.4	14.8	2.01	0.20	0.23	9.5	5.87	44.1	3.02	0.51	0.59	2.70	2.63	55.2	5.03	0.48	0.55	75.0	9	0.07
3	16.84	22	11.3	14.8	3.55	0.34	0.39	8.6	8.28	21.1	5.33	0.64	0.73	2.90	1.73	79.1	8.88	0.85	0.97	83.5	9	1.17
7	17.19	23	11.6	15.5	2.38	0.23	0.16	-	-	-	3.57	-	-	2.35	0.95	-	5.95	0.57	0.65	91.0	9	1.4
8	17.19	24	12.9	16.1	1.99	0.24	0.28	8.9	6.3	24.1	2.98	0.44	0.51	2.72	2.5	60.3	4.97	0.60	0.69	69.9	7	0.22
14	17.85	25	12.0	16.8	6.70	0.79	0.91	9.8	8.4	1.0	10.06	1.20	1.38	0.35	0.34	95.0	16.76	1.98	2.26	96.0	4	0.01
15	17.44	22	11.7	14.8	1.97	0.20	0.23	10.1	8.6	12.2	2.96	0.34	0.39	0.48	0.35	95.9	4.93	0.50	0.57	96.1	3	0.13
AVERAGE	17.44	23	11.7	15.5	3.23	0.25	0.38	7.67	5.58	19.3	4.84	0.50	0.77	1.48	1.1	82.5	8.06	0.61	0.94	89.5	7	0.38

*Refers to Soluble P

It was observed therefore, that the Collingwood WPCP provided excellent soluble phosphorus removal for the alum dosages that were applied. However, there was no available reserve of aluminum in the mixed liquor for the occasional high concentration of soluble phosphorus that entered the system. Thus, high influent soluble phosphorus concentrations were transferred directly as high effluent soluble phosphorus concentrations.

4.3 Conclusions of the Collingwood WPCP Monitoring Program

An eleven day monitoring program was conducted over a 28 day period at the Collingwood WPCP in order to evaluate phosphorus removal efficiency. The results of the present study confirmed the historical data in terms of flows, influent BOD_5 and suspended solids concentrations and effluent BOD_5 and phosphorus concentrations. Effluent solids concentrations were found to be lower in the present study than in the historical data, probably due to the differences in sampling methodologies used. There has been a general upwards trend in influent phosphorus concentrations, shown from the historical 1984 and 1985 data, plant data from 1986 and the present study results.

The major factors found to contribute to the poor effluent phosphorus quality at Collingwood WPCP were:

i) insufficient alum addition for complete removal of soluble phosphorus;

ii) variable and high influent soluble phosphorus concentrations resulting from industrial contributions.

5.0 MOORE TOWNSHIP (CORUNNA) WATER POLLUTION CONTROL PLANT

5.1 Plant Description and Historical Performance

5.1.1 Plant Description

The Moore Township water pollution control plant, serving the village of Corunna, is a small extended aeration treatment system. Incoming wastewater is essentially all domestic in origin, with a minor contribution from a fire-fighting school at a local community college.

The original treatment plant, constructed in 1963, was designed to treat a maximum daily flow of 4,360 m^3/d of wastewater, and an average daily flow of 1,450 m^3/d. Additional final clarifiers were installed in 1972. The rated maximum daily flow is now 5000 m^3/d.

Design information for the unit processes at the Corunna WPCP are summarized in Table 5.1. A schematic diagram of the treatment process is provided in Figure 5.1. Upon arrival at the WPCP, the raw wastewater is processed through a 38 cm (15 in) diameter comminutor, before being split equally through two process trains. Comminuted wastewater flows through aerated grit removal tanks of 17 m^3 capacity each resulting in a design HRT of 17 minutes at a design flow of 1,450 m^3/d.

Degritted wastewater flows by gravity into the aeration basins, which are 2 parallel rectangular tanks having dimensions 26.5 m by 5.2 m by 4.3 m deep. The total volume of 1,155 m^3 results in a hydraulic retention time of 19.0 hrs at a design average flow of 1,450 m^3/d. Air from two blowers with a total power rating of 75 kW is introduced into the mixed liquor by porous plate diffusers. Return activated sludge is distributed equally to the two tanks by two centrifugal pumps rated at 2.3 to 2.7 m^3/min.

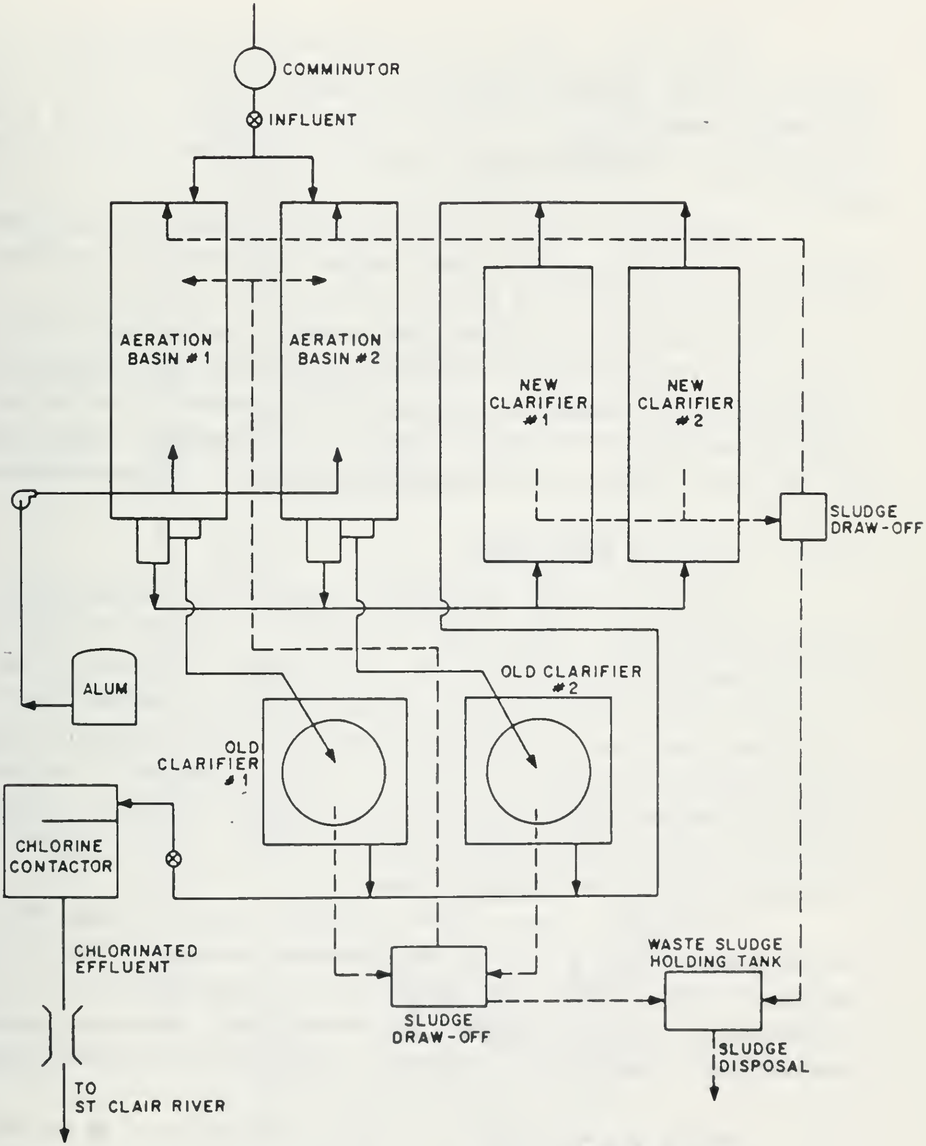
At the end of each aeration tank are two diversion boxes which direct the mixed liquor to an old clarifier or a new clarifier. The approximate flow split, based on the size of the diversion boxes, is 60 percent to the new clarifiers and 40 percent to the old clarifiers.

The original two square tanks have dimensions 6.7 m x 6.7 m x 3.8 m, while the two newer rectangular clarifiers are 15.2 m x 4.3 m x 4.1 m. The HRT of the old clarifiers was 5.7 hrs at a design average flow of 1,450 m^3/d. The surface loading in the old clarifiers was 16.1 $m^3/m^2 \cdot d$. The volume of the new rectangular clarifiers is 878 m^3, while the surface area is 131 m^2.

TABLE 5.1 - DESIGN SUMMARY - MOORE TWP (CORUNNA) WPCP

DESIGN CRITERIA	DESIGN VALUE	OPERATING LEVEL†
Flow (m^3/d)		
Average Daily	1,450 Aeration Tank	2,050
Peak Day	5,001	
BOD Loading (kg/d)		
Peak	750	
Average	217	235
Sewer Collection System	100% Separate	
Bypass - Point	Influent Wet Well	
Frequency	0	
Discharge Point	Final Outfall	
Aeration System		
HRT (hours)	19.0 at 1,455 m^3/d	13.5
BOD Load ($kg/m^3 \cdot d$)	0.19 at 1,455 m^3/d	0.20
Return Sludge Rate (%)	DNA	-
Phosphorus Removal		
Chemical	Alum	1984= 7.7 mg Al/L
Average Dose (mg metal/L)		1985= 3.9 mg Al/L
Secondary Clarifier		
HRT (hours)	5.7	10.3
Avg. Surface Loading ($m^3/m^2 \cdot d$)	16.1**	9.3
Peak Surface Loading ($m^3/m^2 \cdot d$)	48.4**	-

† = Based on 1981 - 1985 Historical Data
DNA = Data Not Available
**Design Values for Old Clarifiers



⊗	SAMPLE LOCATION
— — — —	SLUDGE RETURN

FIGURE 5-1 : SCHEMATIC DIAGRAM OF MOORE TOWNSHIP (CORUNNA) WPCP

Liquid alum is added to the mixed liquor at the exit end of the aeration tanks for phosphorus removal. The alum is fed to the addition point by a chemical metering pump. Although the pump discharge rate can be manually adjusted, no adjustments were made to the alum feed rate during this study.

Secondary effluent is disinfected with chlorine prior to discharge to the St. Clair River. The contact chamber was constructed when the new final clarifiers were built in 1972.

The facility has no aerobic or anaerobic digestion tanks, but it is provided with a waste sludge holding tank to concentrate the sludge before it is hauled away for disposal on farm land in dry weather, or to the Sarnia pollution control plant for sludge processing in wet weather. Water decanted from the sludge holding tank is returned to the head of the aeration tanks.

5.1.2 Historical Performance

The annual average performance of the Corunna treatment plant for the years 1981 to 1985 is summarized in Table 5.2. During the five year period, the average daily flow was 2,050 m^3/d, which is 140 percent of the design average flow. Because this is an extended aeration treatment plant with a relatively long hydraulic retention time, the increased hydraulic loading does not appear to affect the process. The raw wastewater is relatively weak, with average influent BOD_5 and total suspended solids (TSS) concentrations of 115 and 122 mg/L, respectively. The influent total phosphorus level during the 5-year period averaged 7.0 mg/L.

The quality of the effluent discharged from the Corunna WPCP from 1981 to 1985 was high, with a BOD_5 concentration averaging 6.4 mg/L (approximately 94 percent removal) and an average TSS concentration of 9.9 mg/L (approximately 92 percent removal). The effluent total phosphorus concentration averaged 0.9 mg/L, with a resulting 87 percent overall removal efficiency.

Monthly average data for the years 1984 and 1985 at the Corunna WPCP are summarized in Table 5.3. With the exception of a concentration of 17.2 mg/L in January, 1984, the BOD_5 concentrations did not exceed 15 mg/L. Total suspended solids similarly averaged less than 15 mg/L with the exception of January and February, 1985, when the concentrations averaged 27.4 and 16.7 mg/L, respectively. Average phosphorus levels fluctuated significantly

TABLE 5.2 - ANNUAL AVERAGE PERFORMANCE OF MOORE TWP (CORUNNA) WPCP

	YEAR					5 YEAR AVERAGE 1981 - 85
PARAMETER	1981	1982	1983	1984	1985	
Avg. Daily Flow (1000 m^3/day)	2.11	1.98	1.90	1.43	2.85	2.05
BOD_5 - Influent (mg/L)	95.6	133.7	101.5	119.3	124.6	114.8
BOD_5 - Effluent (mg/L)	4.5	5.8	4.5	7.5	9.1	6.4
TSS - Influent (mg/L)	107.0	159.3	93.3	115.3	138.3	122.1
TSS - Effluent (mg/L)	11.5	9.2	10.5	8.8	9.6	9.9
Total P - Influent (mg/L)	6.76	6.71	6.98	6.36	7.86	6.95
Total P - Effluent (mg/L)	0.93	0.61	0.98	0.87	0.85	0.85

5.3 - MONTHLY AVERAGE QUALITY (1984-1985) OF MOORE TWP (CORUNNA) WPCP EFFLUENT

YEAR	MONTH	EFFLUENT BOD$_5$ (mg/L)	n BOD	EFFLUENT TSS (mg/L)	n TSS	EFFLUENT TP (mg/L)	n TP
1984	JAN.	17.2	2	14.4	2	0.42	2
	FEB.	5.9	1	11.7	1	0.34	1
	MAR.	10.0	2	11.4	2	1.30	2
	APR.	7.8	3	7.7	3	0.30	3
	MAY	3.7	1	7.6	1	0.21	1
	JUN.	8.0	2	10.3	2	1.05	2
	JUL.	6.4	2	6.1	2	1.11	2
	AUG.	6.2	2	4.9	2	0.76	2
	SEP.	4.7	2	5.6	2	1.08	2
	OCT.	5.8	2	7.4	2	1.04	2
	NOV.	5.4	2	8.6	2	1.70	2
	DEC	8.7	2	10.1	2	1.07	2
1985	JAN.	14.3	1	27.4	1	2.45	1
	FEB.	12.1	2	16.7	2	1.31	2
	MAR.	4.3	1	6.4	1	0.24	1
	APR.	7.7	2	6.9	2	0.25	2
	MAY	10.8	2	12.5	2	0.63	2
	JUN.	10.3	2	9.8	2	0.37	2
	JUL.	13.6	2	5.0	2	0.61	2
	AUG.	7.1	1	4.3	1	0.55	1
	SEP.	7.5	1	5.7	1	1.06	1
	OCT.	4.1	1	4.6	1	1.20	1
	NOV.	5.2	1	7.4	1	1.09	1
	DEC	12.4	1	8.0	1	0.47	1

n - Number of samples

about the 1.0 mg/L standard. In 1984, seven monthly averages exceeded the 1.0 mg/L limit, while in 1985, 5 montnly averages were higher than this level. The monthly averages are based on only one or two samples per month, however, and as a result may not be entirely representative of overall plant performance.

5.1.3 Sampling Program

The Corunna WPCP was sampled from September 10 to September 30, 1986. Twelve daily composite samples of raw wastewater and final effluent were collected during this period on weekdays. Grab samples of mixed liquor, return activated sludge and alum were also collected on each sampling day. Sampling locations were depicted in Figure 5.1.

The raw wastewater sample was a 24 hour composite, collected after the comminutor, while the secondary effluent sample was a 24 hour composite collected before the chlorine contact chamber. At this plant, a 24 hour flow-proportioned composite sample could not be formulated because the installation of a new ultrasonic flow meter with electronic readout did not store instantaneous flows at different time intervals, only average, maximum and minimum readings.

Soluble phosphorus samples were filtered on-site immediately after collection. BOD_5 samples were frozen, while the remainder of the samples were refrigerated until shipment to CANVIRO (maximum 2 days holding period). Samples were shipped to CANVIRO's laboratory in coolers with ice packs using a courier service.

5.2 Results of Sampling Program

Operating data for the Corunna WPCP during the sampling period are summarized in Table 5.4. The average flow to the plant during this sampling period was 2,407 m^3/d, which is approximately 166 percent of the design average flow through the aeration section. The flow during the last ten days of the sampling program was substantially higher than the earlier part of the study at this plant due to rainfall. Peak flows in excess of 5,000 m^3/d were noted on 3 days during this study.

The treatment plant operators control the biological process by the sludge wasting rate, which is determined by the mixed liquor suspended solids concentration. The treatment plant operators try to maintain an upper limit

TABLE 5.4 - OPERATING CONDITIONS AT MOORE TWP (CORUNNA) WPCP (SEPT. 8-30, 1986)

DATE (1986)	FLOW (1000 m^3/d)		MLSS		RAS* (mg/L)	WAS (m^3)	ALUM* (L)	Al DOSAGE** (mg/L)	SRT (days)
	TOTAL	MAX	Conc'n (mg/L)	%Volatile*					
Sept 8	1.792	3.377	3,552			13	--		
9	1.730	3.408	3,609			13	--		
10	2.084	3.648	3,449	62.0	14,900	13	323	8.68	19.4
11	2.409	4.251	3,502	64.1	16,060	22	314	7.30	
12	1.978	3.365	3,399			22	--		
13	1.816	3.596	3,473				--		
14	1.914	4.949	3,597				--		
15	2.882	5.274	3,725	64.2	15,580	22	311	5.72	13.5
16	1.978	3.620	3,661	64.5	8,180	45	305	8.63	
17	1.942	3.694	3,228	64.0	11,420	22	324	9.34	
18	1.933	3.961	2,853	66.5	15,700	13	323	9.36	
19	1.912	2.270	3,299			22	--		
20	1.927	2.914	3,285				--		
21	2.218	7.804	3,398				--		
22	3.824	7.902	3,396	60.1	20,820	22	308	4.51	10.1
23	1.853	5.469	3,356	64.2	19,680	45	317	6.22	
24	2.418	4.358	3,184	62.4	13,420	22	312	7.22	
25	2.216	3.840	2,815	61.1	17,800	13	315	7.96	
26	2.593	5.035	3,240			22	--		
27	3.345	6.692	3,333				--		
28	2.951	4.278	3,240				--		
29	3.333	6.407	3,281	62.8	17,420	22	314	5.27	9.4
30	3.327	5.636	3,634	61.7	12,960	45	310	5.22	
AVERAGE	2.407	-	3,370	63.1	15,330	23	315	7.11	
MAXIMUM	3.824	7.902	3,725	-	20,820	-	324	9.36	
MINIMUM	1.730	2.194	2,815	-	8,180	-	308	4.51	

of 3,000 to 3,100 mg/L. The wasting rate is increased if the mixed liquor suspended solids concentration increases above this upper limit, while the wasting is decreased when the MLSS concentration declines much below 3,000 mg/L. Consequently, the solids retention time (SRT), calculated from data provided by the plant and analyzed from the collected samples, fluctuated considerably on a daily basis. On an average weekly basis, the SRT declined steadily during the study from 19.4 days at the start to 9.4 days at the end.

Liquid alum was metered to the exit end of the aeration tanks at a constant nominal rate of 315 L/d during this study. Because the alum feed rate was constant, the alum dosage varied inversely with the wastewater flow. The estimated mean aluminum dosage rate was 7.1 mg/L of wastewater with a range of 4.5 to 9.4 mg/L.

The BOD_5 and total phosphorus levels measured in the raw wastewater during the monitoring program (Table 5.5) were lower than the average concentration reported for the previous five years in Table 5.2. The mean total suspended solids levels in this study was similar to mean annual averages from previous years. The observed weaker wastewater may be due to collection of 24 hour composite samples in this monitoring program, rather than 16 hour composites which are routinely collected by the operating staff. Inclusion of raw wastewater from the early morning hours may have a diluting effect on the total influent sample. In the last week of the monitoring program, substantial periods of rain may also have resulted in a more dilute wastewater entering the plant.

The treatment plant produced a high quality effluent during the sampling program. Monitoring data are reported in Table 5.5. The average BOD_5 concentration in the effluent was 2.3 mg/L with a range of 1.4 to 3.0 mg/L. The mean effluent TSS concentration was 7 mg/L with minimum and maximum values of 5 and 10 mg/L, respectively. Average total and filterable phosphorus concentrations were 0.6 and 0.3 mg/L, respectively. The distributions of phosphorus concentrations observed during this monitoring program are presented in Figure 5.2. Filterable phosphorus represented 68 percent of total phosphorus in the raw wastewater, and 58 percent of total phosphorus in the secondary effluent.

Mean removal efficiencies of BOD_5 and TSS were 97 percent (range of 95 to 98 percent) and 92 percent (80 to 98 percent), respectively. Both total and filterable phosphorus were removed efficiently, with mean removals of 89 percent (83 to 84 percent) for total phosphorus, and 90 percent (83 to 94 percent) for soluble phosphorus.

TABLE 5.5 PERFORMANCE MONITORING DATA FOR MOORE TWP (CORUNNA) WPCP

DATE	CONCENTRATION (mg/L)										REMOVAL (%)			
	RAW					FINAL EFFLUENT								
	BOD_5	TSS	TOTAL P	FILT. P	FILT. P (% of Total)	BOD_5	TSS	TOTAL P	FILT. P	FILT. P (% of Total)	BOD_5	TSS	TOTAL P	FILT. P
Sept. 10	60	240	4.8	3.5	73	1.4	6	0.6	0.3	50	98	98	88	91
11	90	180	5.7	3.4	60	2.5	5		0.3	50	97	97	89	91
15	93	220	5.9	3.2	54	2.0	6	0.6	0.3	50	98	97	90	91
16	79	110	5.7	3.6	63	2.0	5	0.6	0.3	50	97	95	89	92
17	90	90	7.2	5.7	79	2.2	6	0.4	0.4	100	98	93	94	93
18	95	90	3.9	4.4	79	1.8	6	0.5	0.3	60	98	93	91	93
22	85	200	3.9	1.8	46	3.0	9	0.4	0.3	75	96	96	90	83
23	55	60	3.3	3.3	69	2.6	8	0.7	0.3	43	95	87	85	91
24	70	60	4.6	3.9	85	2.1	7	0.6	0.3	50	97	88	87	92
25	85	60	6.0	4.5	75	2.3	7	0.5	0.3	60	97	88	92	93
29	60	50	4.2	3.7	88	3.0	10	0.7	0.4	57	95	80	83	89
30	60	70	4.0	1.9	48	2.4	8	0.6	0.3	50	96	59	85	94
Mean	77	120	5.2	3.6	68	2.3	7	0.6	0.3	58	97	92	89	90
Std. Dev.	15	70	1.0	1.1	14	0.47	2	0.1	0.04	16	1.1	5.4	3.1	3.4
Min.	55	50	3.9	1.8	46	1.4	5	0.4	0.3	43	95	80	83	83
Max.	93	240	7.2	5.7	88	3.0	10	0.7	0.4	100	98	98	94	94

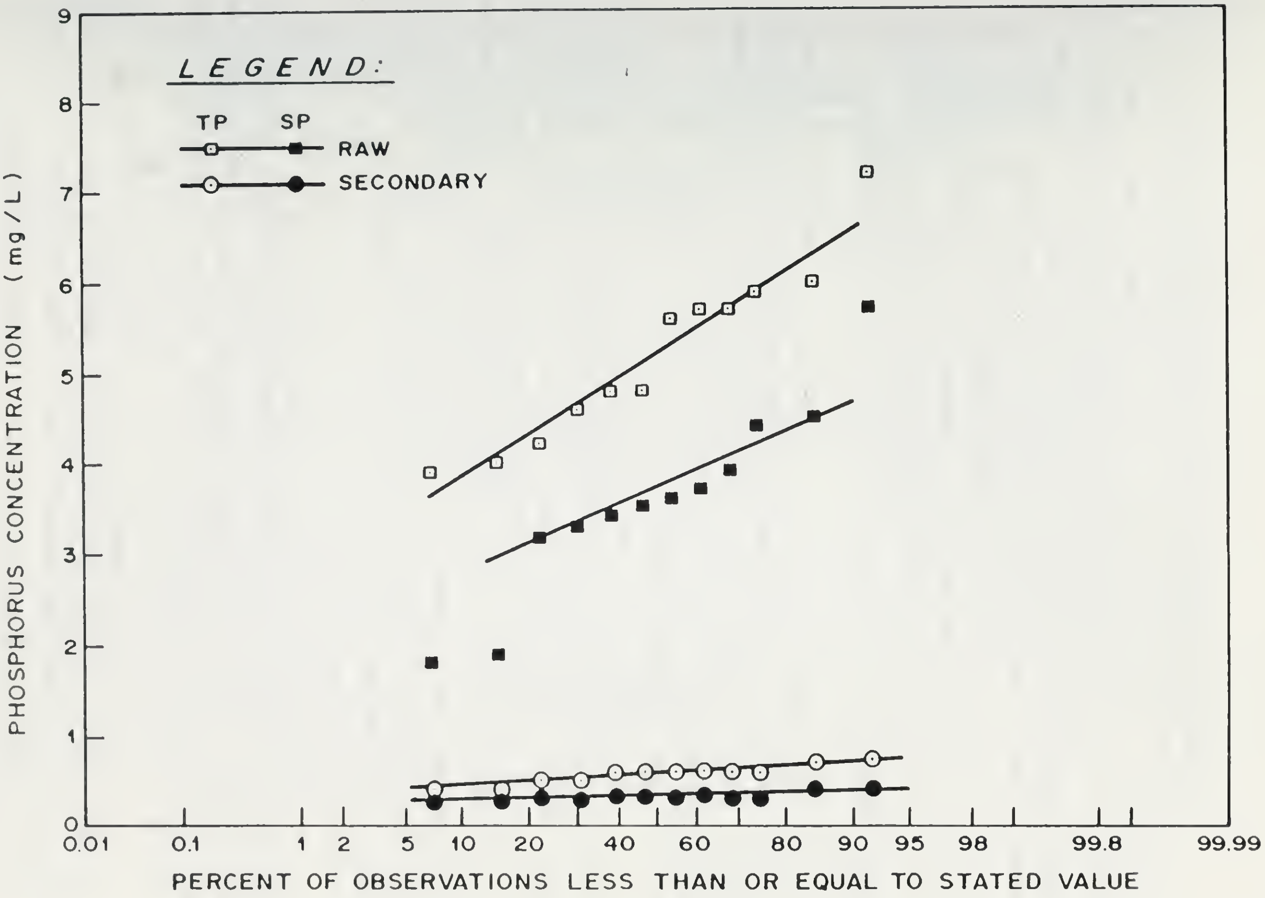


FIGURE 5-2: PROBABILITY DISTRIBUTIONS FOR PHOSPHORUS CONCENTRATIONS AT THE CORUNNA WPCP

Key operating parameters which affected phosphorus removal at the Corunna WPCP are summarized in Table 5.6. The average hydraulic loading on the clarifiers was 11.8 $m^3/m^2 \cdot d$, while the peak loading was 22.0 $m^3/m^2 \cdot d$. These values are substantially less than the 35 $m^3/m^2 \cdot d$ peak loading recommended by the MOE for extended aeration plants. In addition to the low hydraulic loading on the clarifiers, the sludge volume index (SVI) calculated by the operating staff ranged between 59 and 70, indicating that the mixed liquor settled very well. Because these factors minimized the carry over of biological solids in the secondary effluent, particulate phosphorus comprised only 0.3 mg/L or 50 percent of the total phosphorus in the effluent.

The average Al:soluble P molar ratio was 2.4, relative to a stoichiometric ratio of 1. The estimated chemical dosage during the study was 7.1 mg Al/L, which is similar to the aluminum dosage reported for 1984 and nearly doubled the dosage for 1985 (Table 5.1). The chemical dosages resulted in a low filterable phosphorus concentration of 0.3 in the final effluent.

In comparison with the historical data for phosphorus removal at the Corunna WPCP, effluent total phosphorus concentration never exceeded 1.0 mg/L. Several factors may account for this. The alum dosage rate observed in this study was approximately 220 mL/min, whereas in 1985 the reported dosage rate was 130 mL/min. Based on typical aluminum concentrations of commercial alum, the aluminum dosage rate in this study was 7.1 mg/L, relative to a calculated dosage for 1985 of 3.9 mg/L, and 7.7 mg/L in 1984. In 1985, at least, a low aluminum dosage may have been partly responsible for phosphorus concentrations exceeding 1.0 mg/L.

Total phosphorus levels in 1984 and 1985 were 6.36 and 7.86 mg/L, respectively, whereas in this study, the mean total phosphorus concentration was 5.2 mg/L. Lower total phosphorus concentrations in this montoring period may also have contributed to more consistent phosphorus removal efficiency relative to historical results.

It should also be noted from the historical data in Table 5.3 that very low monthly effluent total phosphorus levels (e.g. 0.21, 0.24, 0.25 mg/L) are interspersed with concentrations in excess of 1.0 mg/L. This monitoring program may have occurred in one of the time intervals when a satisfactory phosphorus removal efficiency was achieved. Because the historical data consist of only one or two samples per month, monthly averages may be based on a sampling frequency that is inadequate to accurately characterize the phosphorus removal efficiency of the plant.

TABLE 5.6. SUMMARY OF KEY OPERATING PARAMETERS FOR MOORE TWP (CORUNNA) WPCP

DATE	CLARIFIER LOAD ($m^3/m^2 \cdot d$)		SVI*	Al DOSE (mg/L)	Al:Sol. P RATIO		EFFLUENT CONCENTRATION (mg/L)			
	AVG.	PEAK			WEIGHT	MOLAR	TSS	PARTICULATE P	SOLUBLE P	TOTAL P
Sept 10	9.5	16.5	61	8.68	2.5	2.8	6	0.3	0.3	0.6
11	10.9	19.3	59	7.30	2.1	2.5	5	0.3	0.3	0.6
15	13.1	24.0	62	5.72	1.8	2.1	6	0.3	0.3	0.6
16	9.0	16.4	62	8.63	2.4	2.8	6	0.3	0.3	0.6
17	8.8	16.8	61	9.34	1.6	1.9	6	0	0.4	0.4
18	8.8	18.0	70	9.36	2.1	2.4	6	0.2	0.3	0.5
22	17.3	35.9	61	4.51	2.5	2.9	9	0.1	0.3	0.4
23	13.0	24.8	60	6.22	1.9	2.2	8	0.4	0.3	0.7
24	11.0	19.8	60	7.22	1.9	2.1	7	0.3	0.3	0.6
25	10.1	17.4	64	7.96	1.8	2.0	7	0.2	0.3	0.5
29	15.1	29.1	67	5.27	1.4	1.6	10	0.3	0.4	0.7
30	15.1	25.6	66	5.22	2.7	3.2	8	0.3	0.3	0.6
MEAN	11.8	22.0	63	7.11	2.1	2.4	7	0.3	0.3	0.6

*MOE operating data

A final factor which may influence phosphorus removal efficiency is the periodic occurrence of excessive foam in the aeration tanks and floating sludge in the final clarifier. The latter problem could have a significant impact on conventional pollutant concentrations. While some foam was observed on the aeration tanks on a few days of this study, it had no apparent effect on the superior performance of the treatment plant.

5.3 Conclusions of Corunna WPCP Phosphorus Monitoring Program

The monitoring program at the Corunna WPCP confirmed that the treatment plant produces a high quality effluent in terms of BOD_5 and TSS, as indicated by historical data. In contrast to monthly historical data for 1984 and 1985, in which total phosphorus concentration exceeded the 1.0 mg/L limit 50 percent of the time, total phosphorus levels in the effluent never exceeded 10 mg/L in this study. Possible reasons for the improvement in phosphorus removal efficiency include:

(i) an aluminum dosage as great or greater than previous years;
(ii) influent phosphorus levels lower than historical concentrations;
(iii) collection of an adequate number of samples to characterize the removal efficiencies; and,
(iv) sampling during a period of exceptional plant performance.

Although some foam was apparent in the aeration tanks during the study, floating sludge, which has been a problem in the past at this plant, did not develop in the final clarifiers.

Factors resulting in efficient phosphorus removal at the Corunna plant during this period were:

(i) low secondary clarifier hydraulic loadings;
(ii) biological solids that settle very well;
(iii) satisfactory Al:soluble P ratio.

Although the alum dosage rate is rarely adjusted, the effluent phosphorus concentration is effectively controlled by maintaining a low, relatively constant contribution from particulate P, and maintaining a substantial reserve of aluminum n the biological process because of the long solids retention time associated with the extended aeration process.

6.0 ST. THOMAS WATER POLLUTION CONTROL PLANT

6.1 Plant Description and Historical Performance

6.1.1 Plant Description

The St. Thomas Water Pollution Control Plant (WPCP), serving a population of 27,482 people, is an activated sludge plant with a somewhat complex operation due to several expansions. The contribution from industry to the total wastewater flow is significant particularly from large plants (e.g., manufacturers of roller bearings, heavy lifting equipment, lead-acid batteries) in the industrial park in the city's east end. The pollution control plant is operated by the City of St. Thomas.

Four small, nearly independent treatment plants comprise the St. Thomas plant. The peak flow treated by primary clarification is 68,180 m^3/d, while the design average daily flow for the combined secondary treatment plans is 26,820 m^3/d. The design average flows for plant No.'s 2, 3 and 4 are 4,540 m^3/d, 9,080 m^3/d and 8,630 m^3/d, respectively. Plant No. 1, which was not in operation at the time of this study for energy conservation and operating cost reductions, has a design average flow of 4,540 m^3/d. The No. 1 plant location is distant from the remaining three plants (over 700 m) near the south end of the property resulting in greater efforts for sampling, process control and maintenance.

Design information for the unit processes in operation at the St. Thomas treatment plant are summarized in Table 6.1. A schematic diagram of the plant is provided in Figure 6.1. Raw wastewater arriving at the plant first passes through a 1.4 m wide coarse bar screen with 2.5 cm bar spacings. The screen is automatically raked. Screened wastewater flows into an aerated grit tank, of dimensions 12.0 m x 6.3 m x 5.25 m deep, providing a design average detention time of 31.3 min., and a detention time of 8.4 min at the design peak flow.

Degritted raw wastewater is then split by flow controlling equipment and directed to plant No.'s 2, 3 and 4. Plant No. 2 consists of two parallel trains of primary clarifier, aeration tanks and secondary clarifiers. The primary clarifiers of plant no. 2 have dimensions of approximately 17.2 m x 4.9 m x 4.0 m deep. The combined hydraulic retention time (HRT) at design average flow conditions is 3.5 hr, and the total surface

TABLE 6.1 - DESIGN SUMMARY - ST. THOMAS WPCP

DESIGN CRITERIA	DESIGN VALUE	OPERATING LEVEL*
Flow (1,000 m^3/d)		
Peak Day	68,180 (Primaries)	
Average Daily #1	4,540 (Not in use)	
#2	4,540	Total Plant=21,840
#3	9,080	
#4	8,630	
BOD_5 Loading (kg/d)	-	1,736
Sewer Collection System	81% Separate 19% Combined Est.	
Bypass - Point	After primary clarifiers	
- Frequency	-	Est. 2-3 events/yr
- Discharge Point	Chlorine contactors	
Primary Clarifiers		
HRT (hours) #2	3.5	Total Plant = 5.2
#3	2.5	
#4	8.7	
Avg. Surface Load ($m^3/m^2 \cdot d$) #2	27	Total Plant = 15.8
#3	37	
#4	11	
Peak Surface Load ($m^3/m^2 \cdot d$) #2	69	-
#3	94	
#4	28	
Aeration System		
HRT (hours) #2	8.6	Total Plant = 9.5
#3	6.0	
#4	8.7	
BOD_5 Load ($kg/m^3 \cdot d$) #2	-	Total Plant = 0.20
#3	-	
#4	-	
Return Sludge Rate (%) #2	DNA**	DNA
#3	DNA	DNA
#4	DNA	DNA
Phosphorus Removal		
Chemical	Liquid Alum	
Average Dosage (mgAl/L)	-	1985 = 3.1
Secondary Clarifiers		
HRT (hours) #2	4.7	Total Plant = 4.8
#3	2.4	
#4	4.7	
Avg. Surface Load ($m^3/m^2 \cdot d$) #2	20	Total Plant = 19.1
#3	40	
#4	19	
Chlorination		
HRT at avg. flow (min) #2 & #3 south	35	Total Plant = 50
#4 & #3 north	35	

* Average Data for Years 1981 - 1985, and including operation of No. 1 plant which is not presently in use.

**DNA = Data not available.

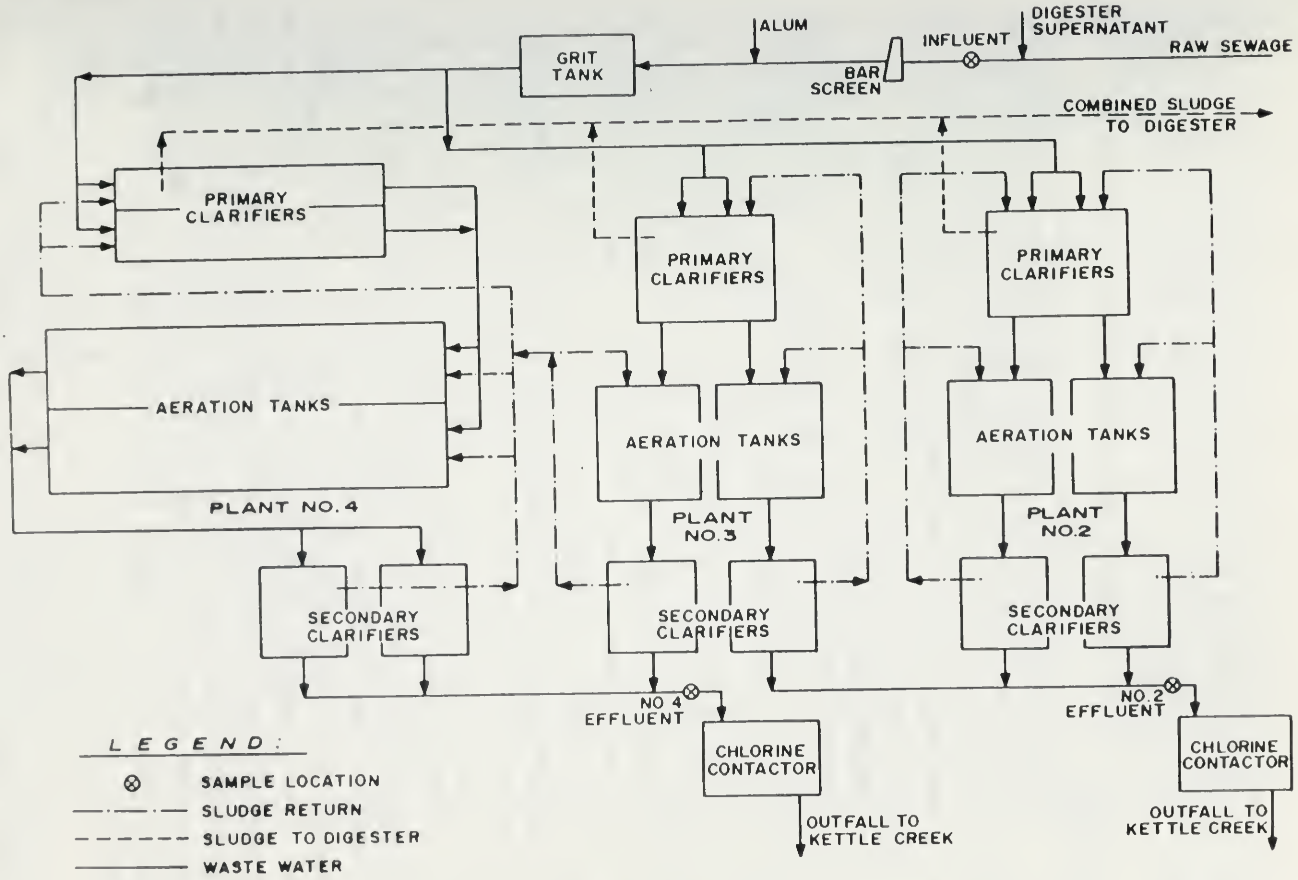


FIGURE 6-1 : SCHEMATIC DIAGRAM OF ST. THOMAS WPCP

loading rate is 27 $m^3/m^2 \cdot d$ at design average flow, and 69 $m^3/m^2 \cdot d$ at peak flow. Primary effluent from each clarifier enters the aeration tanks, which have a combined volume of 1,620 m^3. The aeration capacity results in a HRT of 8.6 hrs at average design flow. Air is supplied to the coarse bubble diffusion system by a 112 kW blower, which also provides air for plant No. 3 and the grit tank.

The rectangular secondary clarifiers of plant No. 2 have dimensions of 23.1 m x 4.9 m x 4.0 m deep, resulting in combined surface area and volume of 226 m^2 and 895 m^3, respectively. Secondary effluent from the two clarifiers is combined with the effluent from the south clarifier of No. 3 plant for chlorination in a 10.7 m x 7.0 m x 3.0 m deep contact chamber. The HRT at design average flow is 35 minutes.

Settled biological sludge from the secondary clarifiers is returned continuously to each aeration tank by air lift pumps. Manual changing of valves directs the return sludge to the primary clarifiers for wasting.

Plant No. 3 consists of two parallel trains of primary clarifiers, aeration tanks and secondary clarifiers. The primary clarifiers (24.8 m x 4.9 m x 4.0) have a total surface area of 243 m^2 and a combined volume of 964 m^3. The design HRT based on average flow is 2.5 hr. Design surface loading rates are 37 $m^3/m^2 \cdot d$ at average daily flow and 94 $m^3/m^2 \cdot d$ at peak flow. Primary effluent flows to the two aeration tanks, which have a combined capacity of 2,280 m^3. THe HRT of the aeration tanks is 6.0 hr at average design flow.

Mixed liquor is discharged into each of the two 23.3 m x 4.9 m x 4.0 m deep secondary clarifiers. Combined surface area of the No. 3 plant clarifiers is 228 m^2, while the total volume is 902 m^3. The HRT and surface loading rate at design average flow are 2.4 hr and 40 $m^3/m^2 \cdot d$, respectively. Excess biological sludge from the south clarifier is returned to the south aeration tank by air lifts, while a centrifugal pump, with a design rating of 3980 L/min at 3.66 m TDH, is used for returning sludge from the north clarifier of No. 3 plant to the north aeration tank. Sludge is wasted from the north clarifier of No. 3 plant to the sludge wasting line of plant No. 4.

As noted above, effluent from the south clarifier of plant No. 3 is chlorinated with the combined secondary effluent from No. 2 plant. The effluent from No. 3 north final clarifier is discharged, together with the

No. 4 plant effluent, to a chlorine contact chamber of dimensions 9.6 m x 8.0 m x 4.1 m, which has a nominal HRT of 35 min at average design flow. Disinfected effluent from both contact chambers is discharged into nearby Kettle Creek.

Plant No. 4 also consists of two parallel treatment trains of primary clarifiers, aeration tanks and secondary clarifiers. The design hydraulic capacity of this individual plant has been down-rated to promote nitrification, according to operating staff. In actual operation during this study, No. 4 plant was treating all flow in excess of approximately 9,900 m^3/d which was substantial at times, as discussed later in this report.

The dimensions of the primary clarifiers are 82.3 m x 4.9 m x 3.9 m. The combined surface area of the two tanks is 806 m^2, while the total volume is 3112 m^3. The capacity results in a HRT of 8.7 hr at average design flow. The surface loading rates at design average and peak flows are 11 and 28 $m^3/m^2 \cdot d$, respectively.

The aeration tanks of No. 4 plant have a total volume of 3,120 m^3, resulting in a HRT of 8.7 hr at average design flow. Air is supplied to a fine bubble diffusion system (No. 4 plant only) by a 93 kW blower, dedicated to this plant only.

The two secondary clarifiers (47.5 m x 4.9 m x 3.7 m deep) have a combined surface area of 464 m^2, which results in a surface loading rate of 19 $m^3/m^2 \cdot d$ at design average flow. With a total volume of 1,696 m^3, the HRT of the final clarifiers is 4.7 hr. Settled sludge is returned equally to the aeration tanks by two centrifugal pumps, rated at 3,980 L/min at 3.66 m TDH. Excess sludge from the No. 4 plant final clarifiers is pumped to the primary clarifiers. The waste biological sludge includes a component from the north clarifier of plant No. 3. Secondary effluent from No. 4 plant and No. 3 north is chlorinated prior to discharge to Kettle Creek.

Phosphorus removal at the St. Thomas WPCP is accomplished by addition of alum to the screened raw wastewater. This addition point was selected because of the complexity of feeding liquid alum from a central storage tank to three and possible four addition points, and the long distances for pumping the alum at low flow rates, especially during winter when freeze-up of the lines may be a problem.

Raw combined sludge from the primary clarifiers is pumped to a series of three 778 m^3 digesters. Active mixing is promoted in only the first digester in the series. Approximately 77 m^3/d of raw combined sludge is pumped to the primary digester daily, resulting in a detention period of 10 days in each digester. Supernatant from the quiescent digesters is returned to the WPCP upstream of the raw sewage sample point.

Digested sludge is withdrawn from the bottom of the third digestion tank in series to an Alfa-Laval centrifuge, where it is concentrated to approximately 20 percent solids by weight, for disposal in the local landfill. Centrate is returned with digester supernatant to the head of the plant. Sludge drying beds are also used in warm weather to dewater sludge, and the dried sludge is hauled to the local landfill for disposal.

6.1.2 Historical Performance

Annual average operating data for the years 1981 to 1985 inclusive are summarized in Table 6.2. For this period, excluding 1981 for which no average flow was recorded, the mean annual average flow was 17,790 m^3/d. Flows have remained relatively steady since 1983.

The raw wastewater is typically dilute, with mean annual average concentrations of 79.5 mg/L for BOD_5 and 121.1 mg/L for total suspended solids (TSS). The annual influent total phosphorus concentration for this five year period averaged 4.63 mg/L.

The effluent quality during the years 1981 to 1985 was generally high. Annual BOD_5 concentrations ranged from 4.5 to 11.3 mg/L (mean of 7.1 mg/L), while the TSS concentrations with the exception of the annual value in 1981, ranged from 4.0 to 10.9 mg/L (mean of 7.4 mg/L). In 1981 the plant was submerged by flooding and plant performance was greatly impaired. The historical data for total phosphorus indicate that the St. Thomas treatment plant has had difficulty in meeting the 1.0 mg/L limit. Only the annual average for 1983 was below this limit during this period.

Monthly average effluent quality data for the years 1984 and 1985 are reported in Table 6.3. BOD_5 concentrations exceeded 15 mg/L in only two of eleven months reported in 1984, and the BOD_5 never exceeded 15 mg/L in 1985. TSS concentrations exceeded 15 mg/L once in 1984, and twice in 1985. BOD_5 and TSS concentrations were highest in the October samples in 1984 and 1985.

Total phosphorus concentrations in the 23 monthly samples collected were less than 1.0 mg/L in twelve samples. Highest phosphorus concentrations were found in the October samples submitted in both years.

TABLE 6.2: ANNUAL AVERAGE PERFORMANCE OF ST. THOMAS WPCP

PARAMETER	YEAR					5 YEAR AVERAGE 81-85
	1981	1982	1983	1984	1985	
Average Daily Flow (1,000 m^3/d)	0.00	15.46	18.32	18.45	18.94	17.79
BOD_5 - Influent (mg/L)	93.0	60.7	72.6	81.8	89.4	79.5
BOD_5 - Effluent (mg/L)	9.0	4.8	4.5	11.3	6.4	7.1
TSS - Influent (mg/L)	131.7	88.1	137.2	102.1	145.1	121.1
TSS - Effluent (mg/L)	82.6	6.5	4.0	10.9	8.3	7.4*
Total P - Influent (mg/L)	4.46	3.91	5.15	4.39	5.23	4.63
Total P - Effluent (mg/L)	1.34	1.25	0.81	1.20	1.14	1.15

*Excludes 1981 TSS effluent value

TABLE 6.3 - MONTHLY AVERAGE QUALITY (1984-1985)
OF ST. THOMAS WPCP EFFLUENT

YEAR	MONTH	EFFLUENT BOD_5 (mg/L)	n BOD	EFFLUENT TSS (mg/L)	n TSS	EFFLUENT TP (mg/L)	n TP
1984	JAN.	8.0	1	3.8	1	0.99	1
	FEB.	17.2	-	6.7	-	1.22	-
	MAR.	11.0	1	13.6	1	1.18	1
	APR.	13.8	1	9.5	1	0.90	1
	MAY	8.4	1	4.1	1	0.75	1
	JUN.	5.4	1	2.7	1	1.19	1
	JUL.	3.9	1	3.3	1	0.89	1
	AUG.	2.4	1	4.2	1	1.16	1
	SEP.	0.9	1	3.1	1	0.92	1
	OCT.	39.7	1	52.5	1	2.30	1
	NOV.	-	-	-	-	-	-
	DEC	13.8	1	16.3	1	1.72	1
1985	JAN.	4.2	1	3.9	1	0.82	1
	FEB.	5.9	1	3.4	1	1.10	1
	MAR.	10.3	1	11.6	1	1.84	1
	APR.	12.0	1	19.0	1	0.54	1
	MAY	7.7	1	3.4	1	0.86	1
	JUN.	6.7	1	4.8	1	1.38	1
	JUL.	2.7	1	3.6	1	0.93	1
	AUG.	2.3	1	1.5	1	0.82	1
	SEP.	6.7	1	7.4	1	1.64	1
	OCT.	10.7	1	27.5	1	2.31	1
	NOV.	2.5	1	4.3	1	0.73	1
	DEC	5.2	1	8.9	1	0.67	1

n - Number of samples

6.1.3 Sampling Program

The sampling program at the St. Thomas WPCP was carried out from 15 September to 2 October, 1986, inclusive. Twelve daily composite samples of raw wastewater and secondary effluents, comprised of No. 2 plant plus No. 3 plant south (designated as No. 2 effluent) and No. 4 plant plus No. 3 plant north (referred to as No. 4 effluent), were collected. Sampling locations were shown in Figure 6.1. Primary effluent samples were not collected because the wasting of sludge from one plant into another confounds the effect of primary sedimentation and sludge age on phosphorus removal.

Grab samples of mixed liquor and return sludge were collected from each plant daily, and were composited based on aeration tank volume. A grab sample of alum was collected daily as it was metered into the raw wastewater.

6.2 Results of Sampling Program

Operating data for the St. Thomas WPCP during the sampling program are summarized in Table 6.4. The design average daily capacity for combined operation of Plant No.'s 2, 3 and 4 is 22,250 m^3/d. The mean daily flow measured during the sampling program was 21,120 m^3/d, which indicates that the plant was operating at nearly 100 percent capacity. Higher than average flows were observed on September 29 and 30 due to rainfall. A maximum peak flow of 34,730 m^3/d was observed on September 22, again due to rainfall.

Sludge is wasted manually from the biological processes based on mixed liquor suspended solids concentrations and sludge volume index determinations. Neither the air lifts nor the centrifugal pumps have been calibrated, and so the actual sludge wasting rates cannot be calculated at present. Without wasting rate, the solids retention time in the biological processes cannot be calculated accurately.

Mixed liquor suspended solids concentrations at the time this program averaged 2,640 mg/L with a volatile fraction of 64.9 percent. The return activated sludge suspended solids concentration was 5,730 mg/L.

TABLE 6.4 - OPERATING CONDITIONS AT ST. THOMAS WPCP (SEPT. 15 - OCT. 2, 1986)

DATE (1986)	FLOW ($1000m^3/d$)		MLSS		RAS (mg/L)	ALUM (L/d)	Al^{3+} DOSE (mg/L)
	TOTAL	MAX	CONC. (mg/L)	VOLATILE (% of Total)			
Sept 15	21.34	33.69	2,600	64.7	6,140	1,080	2.89
16	17.63	25.32	2,780	70.5	7,720	1,354	4.45
17	17.45	25.32	2,540	70.1	5,400	1,324	4.40
18	16.85	27.13	2,420	65.3	5,540	1,267	4.36
22	22.38	34.73	2,840	63.4	5,580	1,152	2.99
23	21.60	31.45	2,680	65.7	5,940	1,354	3.64
24	18.58	26.96	2,820	68.8	5,120	1,238	3.86
25	19.53	26.78	2,560	65.6	4,860	1,324	3.93
29	26.27	33.35	3,000	62.2	4,980	1,210	2.69
30	26.78	33.09	2,500	58.4	7,380	1,498	3.24
Oct 1	23.76	31.36	2,560	62.5	6,600	1,267	3.09
2	21.25	30.93	2,360	61.0	6,460	1,210	3.30
MEAN	21.12	30.02	2,640	64.9	5,730	1,273	3.57
MAXIMUM	26.78	34.73	3,000	70.5	7,380	1,498	4.45
MINIMUM	17.45	25.32	2,360	61.0	4,720	1,080	2.69

Alum is metered into the raw wastewater at a target rate of 900 mL/min (1,296 L/d). The mean alum flow rate observed during this study was 1,273 L/d, which indicates that the target rate was close to being achieved. The observed range in alum flow rates was 1,080 to 1,498 L/d. The mean dosage of aluminum was 3.57 mg/L of wastewater treated, ranging from 2.19 to 4.45 mg/L. Control of the alum feed rate is relatively good, considering that the rate of addition is controlled by a manually adjusted plastic valve. Alum flows by gravity from the storage tank to the point of addition, and consequently changes in the alum level in the tank result in fluctuations in the feed rate. Manual adjustment is made to maintain the desired dosage.

Monitoring data for the sampling program are summarized in Table 6.5. The mean BOD_5 and TSS concentrations in the raw wastewater were 78 and 160 mg/L, respectively. The total phosphorus concentration during this program was 4.9 mg/L. The mean concentrations of BOD_5 and total phosphorus agree well with the mean annual average concentrations reported in Table 6.2. The mean TSS level observed in the program (160 mg/L) is higher than the mean annual average of 121 mg/L for 1981 to 1985. The raw wastewater samples in this study consisted of a 24 hour composite sample, rather than the 8 hour composite submitted by operating staff for routine analysis. Because early morning wastewater is normally weaker than wastewater collected during regular working hours, the wastewater collected during this study may actually be stronger than that from 1981 to 1985.

The quality of the effluents produced by the treatment plants in this study was observed to be very high. Mean concentrations of pollutants were low and nearly identical in both effluent samples (i.e. No. 2 effluent and No. 4 effluent). Effluent BOD_5 concentrations averaged 2.0 and 2.3 mg/L for plants 2 and 4, respectively. TSS levels in both effluents averaged 7 mg/L. The low effluent suspended solids are due in part to the good settling properties of the mixed liquor. Sludge volume index values recorded by operating staff during this study averaged 87 to 90. Total phosphorus concentrations on all sampling days never exceeded 1.0 mg/L, averaging 0.7 mg/L in No. 2 effluent and 0.8 in No. 4 effluent. Mean soluble phosphorus concentration in No. 2 and No. 4 effluents were 0.5 and 0.6 mg/L, respectively. In raw wastewater, the soluble fraction of the total phosphorus averaged 50 percent, while mean soluble phosphorus fractions were 76 and 78 percent in No. 2 and No. 4 effluent, respectively. Distributions of total phosphorus and soluble phosphorus concentration in St. Thomas samples are presented in Figures 6.2 and 6.3 respectively.

TABLE 6.5. MONITORING DATA FOR ST. THOMAS WPCP (SEPT. 15 TO OCT 2, 1986)

DATE	CONCENTRATION (mg/L)														
	BOD			TSS			TOTAL P			SOLUBLE P			SOLUBLE P (% OF TOTAL P)		
	RAW	#2 EFF	#4 EFF	RAW	#2 EFF	#4 EFF	RAW	#2 EFF	#4 EFF	RAW	#2 EFF	#4 EFF	RAW	#2 EFF	#4 EFF
Sept 15	70	3.0	2.0	160	12	6	3.0	0.5	0.8	1.6	<0.3	0.7	53	<60	88
16	45	2.0	1.6	80	7	6	3.2	0.7	0.9	2.0	0.5	0.6	63	71	67
17	130	2.0	2.0	110	7	5	4.5	0.6	0.9	2.3	0.5	0.8	51	83	89
18	100	3.5	1.9	400	6	6	13.2	0.8	0.6	3.7	0.6	0.6	28	75	100
22	65	1.8	1.5	260	9	5	4.3	0.6	0.8	1.5	0.5	0.7	35	83	88
23	65	1.3	1.7	100	4	4	3.2	0.6	0.6	1.6	0.5	0.5	50	83	83
24	90	1.6	1.54	90	4	4	6.0	0.7	0.7	3.9	0.6	0.7	65	86	100
25	130	20	2.0	170	8	5	5.9	0.8	0.8	3.4	0.6	0.6	58	75	75
29	55	2.0	5.0	120	7	15	3.0	0.7	1.0	1.6	0.5	0.7	53	71	70
30	65	1.2	4.0	170	5	15	3.0	0.6	0.8	1.4	0.5	0.4	47	83	50
Oct 1	70	2.0	2.0	170	9	8	5.1	0.6	0.7	1.7	0.5	0.4	33	83	57
2	48	2.0	2.0	70	4	6	3.8	0.6	0.8	2.5	0.5	0.4	66	83	50
MEAN	78	2.0	2.3	160	7	7	4.9	0.7	0.8	2.3	0.5	0.6	50	78	76
STD. DEV	29	0.64	1.1	93	2	4	2.9	0.09	0.1	0.9	0.08	0.1	13	7.8	18
MIN.	48	1.2	1.5	70	4	3	3.0	0.5	0.6	1.4	<0.3	0.4	28	<60	50
MAX.	130	3.5	5.0	400	12	15	13.2	0.8	1.0	3.9	0.6	0.8	66	86	100

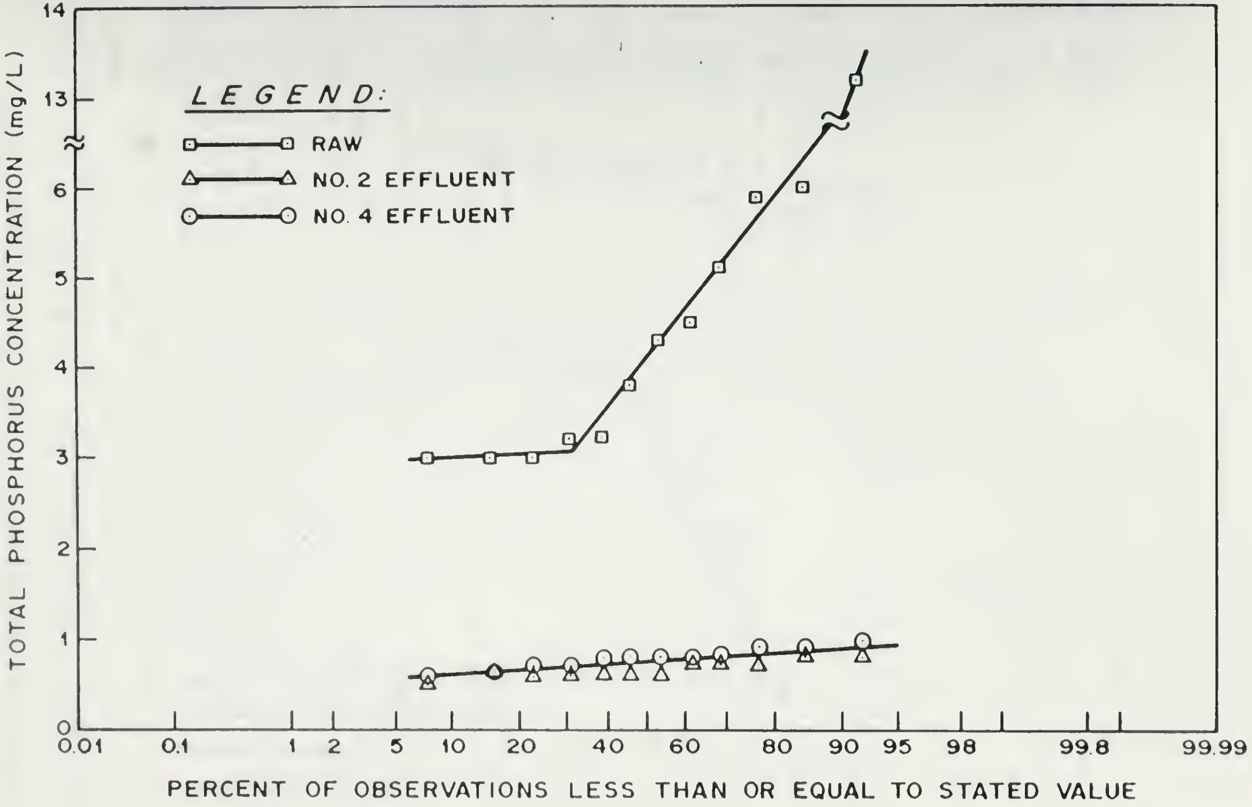


FIGURE 6-2: PROBABILITY DISTRIBUTIONS FOR TOTAL PHOSPHORUS CONCENTRATIONS AT THE ST. THOMAS WPCP

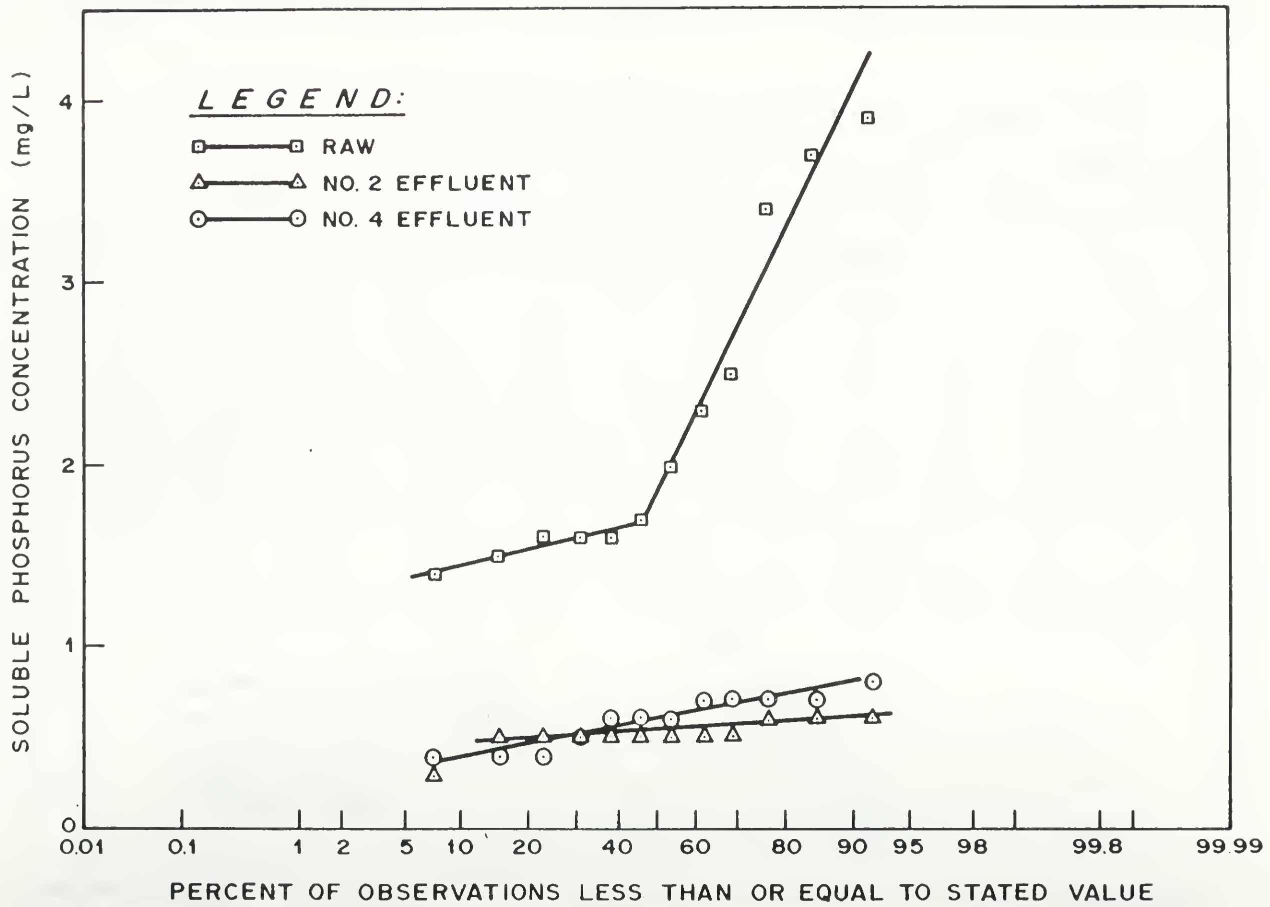


FIGURE 6-3: PROBABILITY DISTRIBUTIONS FOR SOLUBLE PHOSPHORUS

Contaminant removals efficiencies observed during the sampling program are summarized in Table 6.6. Consistently high BOD_5 and TSS removal efficiencies were recorded for both effluents. Mean removals were 97 percent for BOD_5 and 95 percent for TSS in both effluents. Phosphorus reductions were slightly greater in the No. 2 plant effluent than in the No. 4 plant effluent. Soluble phosphorus removal efficiencies averaged 75 percent in No. 2 plant effluent, and 71 percent in No. 4 plant effluent. The lowest removal efficiencies were noted on the first sampling day of each week. Daily flow rates to the plant also tended to be highest on the first day, and consequently the reduced removal efficiency may be flow related.

Mean removal of particulate phosphorus averaged 92 percent in No. 2 effluent and 88 percent in No. 4 effluent. No trends similar to those for soluble phosphorus removal were noted.

Key operating parameters which affected phosphorus removal at the St. Thomas WPCP are summarized in Table 6.7. Because the flows directed to plant No.'s 2 and 3 were maintained at a constant rate, plant No. 4 was subjected to considerable flow variation during this study. The mean flow through plant No. 4 was 130 percent of the design average daily flow; very high flows were observed in the last week of the study (i.e. September 29 to October 1). Excessive flow through plant No. 4 was also noted on the first sampling day of each week (September 15, 22, 29). In comparison, the flows in plant No.'s 2 and 3 were constantly maintained at 104 percent and 57 percent of the design average daily flow, respectively.

The relatively high flows through plant No. 4 resulted in surface loading rates of 35.0 and 35.7 $m^3/m^2 \cdot d$, based on average daily flows, on September 29 and 30. The MOE recommended peak surface loading rate for secondary clarifiers in nitrifying activated sludge plants is 30 $m^3/m^2/d$. The high surface loading rates appeared to result in higher particulate phosphorus and suspended solids concentrations in the third week of the study (September 29 to October 2) in the effluent flow for plant No. 4.

Because alum was metered into the raw wastewater at a constant rate, the fluctuating influent flow rates resulted in a variable aluminum dosage. In addition, the soluble phosphorus concentration was observed to vary from 1.4 to 3.9 mg/L. As a result, the molar Al:soluble P ratio averaged 2.0, and ranged from 1.1 to 2.7. This alum dosage was adequate to provide good phosphorus removal efficiencies during this study.

TABLE 6.6. CONTAMINANT REMOVALS AT ST. THOMAS WPCP (SEPT 15 TO OCT 2, 1986)

DATE	REMOVALS (%)									
	BOD_5		TSS		TOTAL P		SOLUBLE P		PARTICULATE P	
	#2 EFF	#4 EFF	#2 EFF	#4 EFF	#2 EFF	#4 EFF	#2 EFF	#4 EFF	#2 EFF	#4 EFF
Sept 15	96	97	93	96	83	73	>81	56	86	93
16	96	96	91	93	78	72	75	70	83	75
17	98	98	94	95	87	80	78	65	95	95
18	97	98	99	99	94	95	84	84	98	100
22	97	98	97	98	86	81	67	53	96	96
23	98	97	96	96	81	81	69	69	94	94
24	98	98	96	96	88	88	85	82	95	100
25	98	98	95	97	86	86	82	82	92	92
29	96	91	94	88	77	67	69	56	86	79
30	98	94	97	91	80	73	64	71	94	75
Oct 1	97	97	95	95	88	86	71	76	97	91
2	96	96	94	91	84	79	80	84	92	69
MEAN	97	97	95	95	84	80	75	71	92	88
STD. DEV	0.90	2.1	2.1	8.2	4.8	7.9	7.2	11	4.8	11
MIN.	96	91	91	88	77	67	64	53	83	69
MAX.	98	98	99	99	94	95	84	84	98	100

TABLE 5.7. SUMMARY OF KEY OPERATING PARAMETERS FOR ST. THOMAS WPCP

DATE	PLANT NO.	FLOW (1000m³/d)		AVERAGE FLOW (% OF DESIGN)	CLARIFIER LOADING ($m^3/m^2 \cdot d$)		Al DOSE (mg/L)	RAW WASTE SOLUBLE P (mg/L)	Al:SOLUBLE P RATIO		EFFLUENT QUALITY (mg/L)		
		AVG.	PEAK		AVG.	PEAK			WEIGHT	MOLAR	TSS	PART. P	SOL. P
Sept 15	2	4.49	4.49	99	19.8	19.3					12	0.2	<0.3
	3	5.18	5.18	57	22.7	22.7							
	4	11.66	24.02	135	25.1	51.8					6	0.1	0.7
	Total	21.34	33.69	96	-	-	2.89	1.6	1.8	2.1			
16	2	4.67	4.67	103	20.7	20.7					7	0.2	0.5
	3	5.18	5.18	57	22.7	22.7							
	4	7.78	15.47	90	16.8	33.3					6	0.3	0.6
	Total	17.63	25.32	79	-	-	4.45	2.0	2.2	2.6			
17	2	4.67	4.67	103	20.7	20.7					7	0.1	0.5
	3	5.18	5.18	57	22.7	22.7							
	4	7.60	15.47	90	16.8	33.3					6	0.3	0.6
	Total	17.45	25.32	78	-	-	4.40	2.3	1.9	2.2			
18	2	4.67	4.67	103	20.7	20.7					6	0.2	0.5
	3	5.18	5.18	57	22.7	22.7							
	4	7.00	17.28	81	15.1	37.2					3	0	0.5
	Total	16.85	27.13	76	-	-	4.36	3.7	1.2	1.4			
22	2	4.49	4.49	99	198.8	19.8					9	0.1	0.5
	3	5.18	5.18	57	22.7	22.7							
	4	12.70	25.06	147	27.4	54.0					5	0.1	0.7
	Total	22.38	34.73	101	-	-	2.99	1.5	2.0	2.3			
23	2	4.49	4.49	99	19.8	19.8					4	0.1	0.5
	3	5.18	5.18	57	22.7	22.7							
	4	11.92	21.77	138	25.7	46.9					4	0.1	0.5
	Total	21.60	31.45	97	-	-	3.64	1.6	2.3	2.6			
24	2	4.49	4.49	99	19.8	19.3					4	0.1	0.5
	3	5.28	5.18	57	22.7	22.7							
	4	5.90	17.28	103	19.2	37.2					4	0	0.7
	Total	15.58	26.96	84	-	-	3.86	3.9	1.0	1.1			
25	2	4.67	5.01	103	20.7	22.2					8	0.2	0.5
	3	5.27	5.36	58	23.1	23.5							
	4	9.59	16.42	111	20.7	35.4					5	0.2	0.5
	Total	19.53	26.78	88	-	-	3.93	3.4	1.2	1.3			
29	2	4.34	4.34	107	21.4	21.4					7	0.2	0.5
	3	5.18	5.18	57	22.7	22.7							
	4	16.24	23.33	188	35.0	50.3					15	0.3	0.7
	Total	26.27	33.5	118	-	-	2.69	1.6	1.7	1.9			
30	2	5.01	5.01	110	22.2	22.2					5	0.1	0.5
	3	5.18	5.18	57	22.7	22.7							
	4	16.56	22.90	192	35.7	49.4					15	0.4	0.4
	Total	26.78	33.09	120	-	-	3.24	1.4	2.3	2.7			
Oct 1	2	5.01	5.01	110	22.2	22.2					9	0.1	0.5
	3	5.18	5.18	57	22.7	22.7							
	4	13.56	21.17	157	29.2	45.6					8	0.3	0.4
	Total	23.76	31.36	107	-	-	3.09	1.7	1.8	2.1			
2	2	5.01	5.01	110	22.2	22.2					4	0.1	0.5
	3	5.18	5.18	57	22.7	22.7							
	4	11.06	20.74	128	23.8	44.7					6	0.4	0.4
	Total	21.25	30.93	96	-	-	3.30	2.5	1.3	1.5			
MEAN	2	4.71	4.74	104	20.8	20.9					7	0.1	0.5
	3	5.19	5.20	57	22.8	22.8							
	4	11.21	20.08	130	24.2	43.3					6	0.2	0.6
	Total	21.12	30.02	95	-	-	3.57	2.3	1.7	2.0			

In comparison with the historical data for phosphorus removal, effluent total phosphorus concentration never exceeded 1.0 mg/L. Several factors account for this. The operating staff increased the alum feed rate in early 1986 to 900 mL/min. In 1985, the dosage rate was 700 mL/min, and based on annual historical flow and total phosphorus data, the molar Al:total P ratio for 1985 was 0.69. In comparison, the molar Al:total P ratio during the 1986 sampling program was 0.98. This increase in the Al:P ratio may partly explain the better phosphorus removal efficiency observed in this program relative to historical data.

A second factor is the installation of new flow controlling equipment in late summer of 1986 so that the flows to plant No.'s 2 and 3 is constant while plant No. 4 manages the excess flow. In the past, plant No. 3 treated the majority of the wastewater arriving at the WPCP. Plant No. 3 is designed with the shorter HRT's in primary and secondary clarifiers and aeration tanks, and excessive flows through this plant may have resulted in incomplete phosphorus removal due to solids carryover in the effluent. The monthly historical data of 1984 and 1985 (Table 6.3) indicate that many of the highest effluent total phosphorus concentrations are associated with high total suspended solids levels.

A third factor is the number of samples collected for monitoring. The historical data consist of only one sample per month at St. Thomas, which may be inadequate to accurately characterize the phosphorus removal efficiency. This may be especially true if the only sample in the month is taken while the treatment plant is temporarily upset and the effluent quality does not represent normal operation. Also, samples sent by operating staff to the MOE laboratory in London for routine monitoring are manually collected 8 hr composite samples, usually collected during daylight hours when the raw wastewater strength is typically highest. Composite samples collected in this study included nightly sub-samples, which tend to dilute the higher concentrations of day-time wastewater.

6.3 Summary of St. Thomas WPCP Phosphorus Monitoring Program

The monitoring program conducted at the St. Thomas WPCP indicated that the treatment plant is capable of producing a high quality effluent. BOD_5 and TSS concentrations in the effluents from plant No.'s 2 and 3 south were consistently low due to the constant applied wastewater flow. Effluent BOD_5 and TSS concentrations increased significantly when excessive flow was applied to plant No. 4. Total phosphorus concentrations in the two effluent outfalls never exceeded 1.0 mg/L, although the historical data indicated that this limit was exceeded approximately 50 percent of the time in 1984 and 1985.

Possible reasons for the improved phosphorus removal efficiency observed in this study relative to historical performance data are:

(i) higher alum feed rate than previously maintained;

(ii) improved flow distribution to the smaller sub-treatment plants comprising the whole WPCP;

(iii) more representative evaluation of treatment plant performance based on greater sample size;

(iv) collection of 24 hr flow-proportioned composite samples of effluent rather than 8 hr manually composited sample.

Plant No. 4 appears to be subject to hydraulic overloading if the surface loading exceeds 30 $m^3/m^2 \cdot d$, with resulting deterioration of effluent quality. Effluent samples collected during periods of excessively high flow will probably reflect the deteriorating plant performance.

7.0 HUMBER (ETOBICOKE) WATER POLLUTION CONTROL PLANT

7.1 Plant Description and Historical Performance

7.1.1 Plant Description

The Humber WPCP is one of two major secondary treatment facilities serving Metropolitan Toronto. The plant, which is operated by Metro Toronto, was designed as a conventional activated sludge plant with provisions for continuous phosphorus removal. However, the plant is currently operating in the step aeration mode. The plant is designed to handle an average daily flow of 409,140 m^3/day (90 MIGPD) with a peak hydraulic load of 818,296 m^3/day (180 MIGPD). A schematic flow sheet of the plant is provided in Figure 7.1. Available design parameters for the Humber WPCP are summarized in Table 7.1.

Raw sewage is routed to the plant via the Humber Trunk Sewer (2700 cm diameter) from the north and the Queensway Trunk Sewer (1800 cm diameter) from the south. Both these waste streams merge prior to entering the head house. Screening is provided upstream of the head house by bar screens with a 1" spacing. Flow is split up at the head house and routed to the north and south sides of the plant in an approximate 50/50 split. Grit removal for the north split is provided by aerated grit removal tanks. The raw sewage routed to the south side is sent through detritors for grit removal.

Primary sedimentation is facilitated by 6 parallel clarifiers for the south side (#1-6) and 3 parallel clarifiers for the north side (#7-9). Each of the south side clarifiers are 72.2 m by 10.4 m with a liquid depth of 3.1 m providing a total surface area of 4050 m^2 for primary sedimentation. Each of the north side clarifiers are 78.9 m by 25.3 m with a liquid depth of 3.6 m providing a total surface area of 5989 m^2. The total area available for primary sedimentation in the plant is 10,494 m^2. The total primary clarifier volume is 20,935 m^3. Scum removal is accomplished by a wooden flight on endless chain and sprocket in tanks 1 to 4, and a travelling bridge mechanism in primary tanks 5 to 9.

Biological treatment is accomplished in two parallel trains of five (south side) and two (north side) aeration cells. The south side aeration tanks are 139.3 m long by 8.2 m side by 4.6 m deep. The north side aeration tanks are 73.2 m by 17.8 m by 7.5 m. The total aeration volume available is

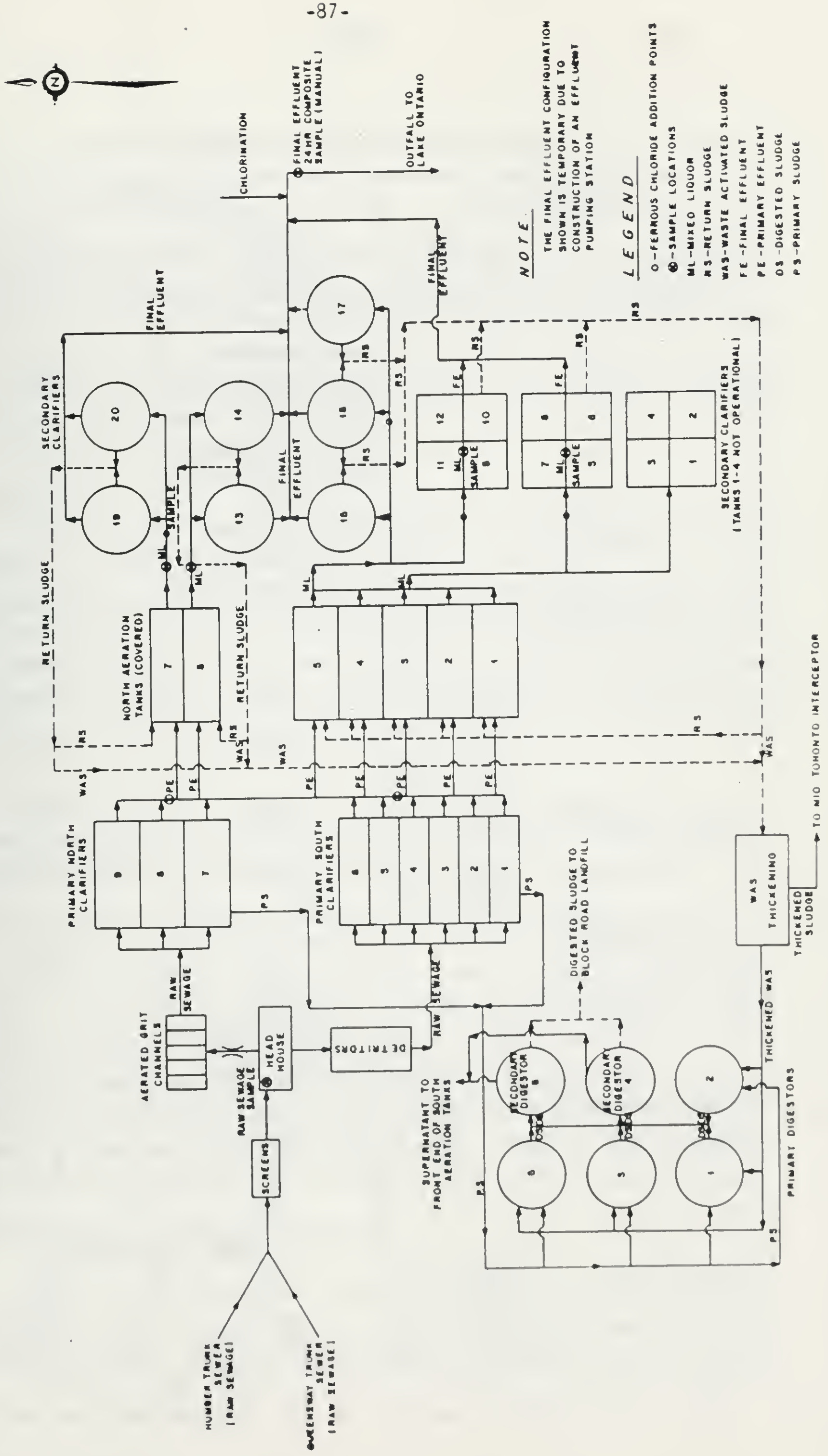


FIGURE 7-1 : SCHEMATIC FLOWSHEET OF HUMBER WPCP

TABLE 7.1 - DESIGN SUMMARY - HUMBER WPCP

DESIGN CRITERIA		DESIGN VALUE	
		AVERAGE	PEAK
Flow (m^3/d)		409,140	818,296
Sewer Collection System		75% separate 25% combined	
Bypass - Point		After primaries for flow >818,296 m^3/d After grit removal for flow >1,022,870 m^3/d	
- Frequency		5-10 per year, after primaries	
- Discharge Point		Outfall	
Primary Clarification			
HRT (hours)		1.2	0.6
Overflow Rate (m^3/m/d)	Tanks 1-6 (South Side)	44.9	120.1
	Tanks 7-9 (North Side)	40.6	120.1
Hydraulic Capacity (m^3/d)	Tanks 1-6 (South Side)	30,000	79,000
	Tanks 7-9 (North Side)	77,000	230,000
Aeration System			
HRT (hours)		2.7	1.3
Return Sludge Rate		100% operated at 100% (night) 40% (day)	
Phosphorus Removal			
Chemical		$FeCl_2$	
Secondary Clarification			
HRT (hours)		5.4 4.6 (operational)*	2.7 2.3 (operational)*
Overflow Rate (m^3/m^2/d)	(North Plant)	18.1	35.4
	(South Plant)	19.9	35.4
Hydraulic Capacity (m^3/d)	(North Plant)	59,000	118,000
	(South Plant)	295,000	535,000

Note: *Final Tanks 1-4 were not in service during the study period.

45,686 m^3. Aeration is by means of a dome diffuser system. Air supply to the south plant is accomplished by three gas engines rated at 900 HP each, as well as an electric blower rated at 1500 HP. Air supply to the north side of the plant is accomplished by a 1500 HP electric blower. Primary effluent and return activated sludge are distributed equally to the aeration cells.

Phosphorus removal is accomplished by ferrous chloride addition to the mixed liquor upstream of the secondary clarifiers. The points of ferrous chloride addition are shown in Figure 7.1. Ferrous chloride is delivered by seven positive displacement pumps from three storage tanks to the addition points. The chemical feed rate is adjusted manually by the pump speed and stroke setting.

Secondary clarification is accomplished by twelve (#1-12) parallel 29 m square clarifiers, and seven (#13-17,#19-20) parallel circular 45.7 m diameter clarifiers. Clarifiers 13, 14, 19 and 20 are utilized specifically for the north side of the plant. The total surface area available for clarification is 21,553 m^2; however during the study period four square clarifiers (#1-4) were not operational, thus reducing the available surface area to 18,199 m^2. The total (available) final clarifier liquid volume was 79,120 m^3.

Return sludge is handled by four 150 HP and fifteen 40 HP vertical centrifugal pumps that are capable of providing 100 percent sludge recycle at design flow. Secondary effluent is chlorinated prior to discharge to Lake Ontario.

Two stage anaerobic digestion is provided for waste activated sludge and primary sludge. Prior to digestion, the waste activated sludge is thickened in an air flotation thickener. Primary sludge is sent directly to the primary digesters. Four primary digesters provide a total volume of 29,095 m^3. The two secondary digesters provide a total volume of 14,547 m^3. Five and a half tonnes of digested sludge per day is routed to the main WPCP incinerator via the mid Toronto interceptor. The remaining digested sludge is landfilled at the Brock Road West landfill.

7.1.2 Historical Performance

Table 7.2 summarizes the annual performance of the Humber WPCP for the years 1981 to 1985. The plant has consistently produced an effluent of relatively low quality, averaging approximately 14 mg/L total BOD_5, 22 mg/L

TABLE 7.2: ANNUAL AVERAGE PERFORMANCE OF HUMBER WPCP

PARAMETER	YEAR					5 YEAR AVERAGE 81-85
	1981	1982	1983	1984	1985	
Average Daily Flow (1,000 m^3/d)	405.96	368.68	365.50	339.55	378.11	371.56
BOD$_5$ - Influent (mg/L)	255.3	259.0	287.0	266.4	264.0	266.3
BOD$_5$ - Effluent (mg/L)	16.4	14.8	14.1	12.7	11.5	13.9
TSS - Influent (mg/L)	348.4	385.0	363.0	385.5	325.6	361.5
TSS - Effluent (mg/L)	24.4	18.7	22.5	26.3	18.2	22.0
Total P - Influent (mg/L)	9.60	10.40	9.04	10.00	8.86	9.58
Total P - Effluent (mg/L)	1.50	1.24	1.04	1.43	1.08	1.26

total suspended solids and 1.26 mg/L total phosphorus for the five year period, 1981 to 1985. During this period the annual effluent total phosphorus concentrations were consistently greater than 1 mg/L. Influent strength has typically been high at 371 mg/L total BOD_5, 362 mg/L total suspended solids and 9.58 mg/L total phosphorus for the five year period. Average daily flow to the plant for the five year period was 371,560 m^3/day (90.8 percent of design flow).

Monthly effluent quality data for 1984 and 1985 (BOD_5, suspended solids and total phosphorus) are presented in Table 7.3. During 1984 effluent phosphorus levels were greater than 1 mg/L for 10 months of the year. Effluent phosphorus levels were slightly better in 1985 and only exceeded 1 mg/L for 6 months of the year. However, none of the monthly average effluent phosphorus levels dropped below 0.5 mg/L for either year. Effluent suspended solids exceeded 15 mg/L for 10 of the months in 1984 and 6 months in 1985. Effluent suspended solids were as high as 58 mg/L (May, 1984). It is interesting to note that during the months when total phosphorus was in compliance with effluent guidelines, the corresponding effluent suspended solids were also relatively low. Effluent BOD_5 exceeded 15 mg/L for four months during the two year period, but stayed below the 25 mg/L level.

7.2 Sampling Program

The Humber WPCP was sampled between August 6, 1986 and September 6, 1986. Twelve daily samples were collected during this period.

Sampling locations were identified in Figure 7.1. A twenty-four hour sample of raw wastewater (after screening) was obtained. Twenty-four hour composite samples of primary effluent were collected from the north and south primary effluent conduits. These samples were flow proportioned to obtain a single composite sample. Twenty-four hour flow-proportioned composite samples of secondary effluent (after chlorination) were also collected. Final tanks 1 to 4 were not in operation during the study. In addition, grab samples of mixed liquor and return sludge were collected to allow SRT calculations to be completed. Grab samples of ferrous chloride were also obtained on a daily basis. The samples were obtained from an air line on one of the ferrous chloride pups. These samples were representative of ferrous chloride

7.3 - MONTHLY AVERAGE PERFORMANCE OF HUMBER WPCP

YEAR	MONTH	EFFLUENT BOD_5 (mg/L)	n BOD	EFFLUENT TSS (mg/L)	n TSS	EFFLUENT TP (mg/L)	n TP
1984	JAN.	10.0	22	13.0	31	0.89	31
	FEB.	6.0	21	9.0	29	0.70	29
	MAR.	16.0	21	26.0	30	1.90	31
	APR.	15.0	20	22.0	30	1.80	30
	MAY	24.0	21	58.0	29	1.10	31
	JUN.	13.0	20	39.0	29	1.10	30
	JUL.	8.0	22	25.0	31	1.12	31
	AUG.	13.0	21	24.0	31	1.60	31
	SEP.	9.0	19	17.0	30	1.10	30
	OCT.	13.0	22	35.0	31	2.50	31
	NOV.	13.0	18	24.0	30	1.60	30
	DEC	12.0	12	23.0	31	1.80	31
1985	JAN.	11.0	22	16.0	31	1.46	31
	FEB.	14.0	20	16.0	28	1.13	26
	MAR.	9.0	21	14.0	31	1.20	31
	APR.	8.0	20	15.0	30	0.92	30
	MAY	14.0	21	23.0	31	0.90	31
	JUN.	20.0	20	34.0	30	1.76	30
	JUL.	20.0	23	26.0	31	1.39	31
	AUG.	6.0	20	11.0	31	0.66	31
	SEP.	8.0	21	14.0	30	0.87	30
	OCT.	12.0	22	24.0	31	1.43	31
	NOV.	7.0	19	11.0	30	0.57	30
	DEC	9.0	17	14.0	31	0.65	31

n - Number of samples

employed throughout the plant, since ferrous chloride from the various storage tanks feed a common header before being pumped to the addition points.

7.4 Results of Sampling Program

Table 7.4 presents operating data for the sampling dates at the Humber WPCP. Average daily flow for these dates was 415,500 m^3/d or 102 percent of plant design. This flow is significantly higher than observed during 1985 (378,110 m^3/d or 92 percent of design). The unusually heavy precipitation during the sampling period contributed to these high flows. Peak flows in excess of 818,296 m^3/d (peak design flow) were observed on three separate occasions during this period.

Control over the biological system is maintained by continuous wasting; however, during the monitoring period the volume wasted varied from a low of 1970 m^3/d to a high of 4400 m^3. Wastage was performed from the return sludge line. The data collected indicates that on the average 2.6 percent of the return sludge was wasted. Solids retention time varied from 0.6 days to 4.2 days, and was generally below 3 days. This was due to the variation in wastage rate as well as the relatively high concentration of solids in the final effluent.

The volume of ferrous chloride added varied dramatically over the monitoring period. The concentration of iron in the ferrous chloride also varied from a low of 29,850 mg Fe/L to a high of 85,755 mg Fe/L. The calculated chemical dosage averaged 5.50 mg Fe/L over the four week sampling period and ranged from 1.3 mg/L to 11.8 mg/L.

The results of the monitoring program are summarized in Table 7.5. Raw wastewater strength, in terms of all parameters, was low compared to historical data. The raw wastewater averaged 190 mg/L BOD_5 and 222 mg/L suspended solids. Raw wastewater total phosphorus levels averaged 8.7 mg/L of which approximately 33 percent was present in soluble form. The lower strength wastewater is consistent with the higher flows experienced during the monitoring period, caused by unusually high rainfall. Effluent quality during the monitoring period differed from historical data. The average effluent BOD_5 was 10.5 mg/L, slightly lower than the five year average (1981-1985) of 13.9 mg/L. The average effluent suspended solids was 50 mg/L,

TABLE 7.4 - SUMMARY OF HUMBER WPCP OPERATING CONDITIONS

DATE (1986)	FLOW ($10^3m^3/d$)		BYPASS	MLSS (mg/L)	MLVSS (%)	RAS (mg/L)	VSS (%)	RETURN ($10^3m^3/d$)	WAS (m)	% OF RETURN FLOW WASTED	$FeCl_2$ (L)	Fe DOSAGE (mg/L)	SRT (days)	COMMENT
	TOTAL	MAX												
Aug 6	486	705		1960	76.5	4780	79.1	53.4	1970	3.7	34299	5.13	4.2	7.6 mm rain
10	323	486		2340	78.6	6940	74.6	176.9	4360	2.5	34299	7.51	3.0	2.6 mm rain
11	386	536		2360	78.0	7060	77.9	176.9	3300	1.9	57616	11.75	3.7	trace of rain
17	393	614		2100	64.8	5720	69.6	153.4	4530	3.0	34299	7.18	2.5	
18	439	832	Duration Unknown	1200	71.7	6940	68.3	165.4	2600	1.6	27439	5.30	2.0	
19	414	582		2160	75.0	6960	60.6	177.5	4060	2.3	35672	3.23	2.4	
20	418	609	Duration Unknown	2200	77.3	6700	77.6	188.7	4400	2.3	13720	1.29	2.5	
25	386	614		2040	73.5			146.6	4330	3.0	37439	2.12		trace of rain
26	459	1068		1900	82.1	5840	77.7	176.9	3830	2.2	25612	2.0	0.6	55.2 mm rain
Sept 4	414	1119		2140	75.7	7680	73.2	123.5	3220	2.6	38406	6.92	2.2	12.8 mm rain
5	500	659	115 min.	2820	75.2	8660	74.6	121.5	3870	3.2	33840	3.64	1.6	
6	386	605		2800	74.3	8980	75.1	121.5	3530	2.9	47560	9.90	2.7	
AVERAGE	415.5	702.4		2168	75.2	6933	73.5		3667	2.6	34183	5.50	2.5	

TABLE 7.5: SUMMARY OF PERFORMANCE MONITORING DATA HUMBER WPCP

		CONCENTRATION (mg/L)			
DATE	STREAM	BOD_5	TSS	TOTAL P	SOLUBLE P
Aug 6	Raw	375	200	6.90	3.83
	Primary Effluent	-	-	11.20	3.40
	Final Effluent	6.7	25	1.1	0.47
Aug 10	Raw	170	280	8.57	2.30
	Primary Effluent	-	-	5.55	2.90
	Final Effluent	4.7	17	<0.45	<0.2
Aug 11	Raw	117	260	9.44	4.18
	Primary Effluent	-	-	NA	2.45
	Final Effluent	4.3	16	0.70	0.21
Aug 17	Raw	116	140	6.05	2.22
	Primary Effluent	-	-	3.50	2.05
	Final Effluent	6	30	<0.45	<0.18
Aug 18	Raw	228	130	6.32	2.62
	Primary Effluent	-	-	4.2	NA
	Final Effluent	8.5	20	0.93	0.99
Aug 19	Raw	301	350	12.0	3.60
	Primary Effluent	-	-	5.40	2.86
	Final Effluent	14.5	30	1.36	0.39
Aug 20	Raw		230	5.80	1.80
	Primary Effluent	-	-	5.26	1.94
	Final Effluent	11	26	1.47	0.53
Aug 25	Raw	180	170	13.67	3.40
	Primary Effluent	-	-	3.47	3.16
	Final Effluent	10	31	1.45	NA
Aug 26	Raw	230	220	9.15	2.25
	Primary Effluent	-	-	4.90	NA
	Final Effluent	13	285	2.25	1.05
Sept 4	Raw	230	180	9.80	3.27
	Primary Effluent	-	-	4.90	3.45
	Final Effluent	17	50	1.46	0.46
Sept 5	Raw	160	260	7.70	2.40
	Primary Effluent	-	-	5.60	2.90
	Final Effluent	18	90	1.81	0.53
Sept 6	Raw	170	240	9.0	2.7
	Primary Effluent	-	-	4.10	2.90
	Final Effluent	12	40	1.44	<0.2
AVERAGE	Raw	190	222	8.7	2.88
	Primary Effluent	-	-	5.28	2.80
	Final Effluent	10.5	55	1.24	0.47

more than double the five year average of 22 mg/L. The high effluent suspended solids concentration was a result of the unusually high rainfall during the sampling period. The total phosphorus in the secondary effluent was 1.24 mg/L, of which 38 percent was present in soluble form. Probability distributions for the total and soluble components of the phosphorus in raw sewage, primary effluent and secondary effluent are presented in Figures 7.2, 7.3 and 7.4. Primary clarification reduced the total phosphorus concentration by approximately 39 percent prior to chemical precipitation.

Key operating parameters affecting phosphorus removal at the Humber WPCP are summarized in Table 7.6. Average final clarifier loadings of approximately 23 $m^3/m^2/d$ were observed, which were higher than the design value of 19 $m^3/m^2/d$. This high hydraulic loading contributed to the high final effluent suspended solids concentrations observed. This was reflected in the high effluent phosphorus concentrations associated with particulate matter. The total phosphorus in the final effluent was high and averaged 1.24 mg/L. Based on soluble phosphorus in the primary effluent, the average Fe:P molar ratio was 1.20, compared to the stoichiometric requirement of 1. The resulting final effluent soluble phosphorus concentrations were generally in agreement with the low metal-to-phosphorus dosage ratio, averaging 0.47 mg/L.

7.4 Conclusions of the Humber WPCP Monitoring Program

The four week monitoring program at Humber WPCP confirmed the poor effluent quality reported historically at this plant in terms of total phosphorus. The final effluent BOD_5 levels were slightly lower and suspended solids levels slightly higher than historically reported. Raw wastewater strength was lower than had been reported due to unusually high rainfalls.

The soluble phosphorus component of total phosphorus in the final effluent was typically approximately 0.5 mg/L, except for two days (August 18, 26) where the concentration was approximately 1 mg/L. The iron content in the ferrous chloride solution varied considerably over the four week duration of the study, making dosage control difficult.

The phosphorus in particulate form constituted a large component of the total phosphorus in the final effluent. This probably resulted from a loss of suspended solids with the final effluent due in part to the rela-

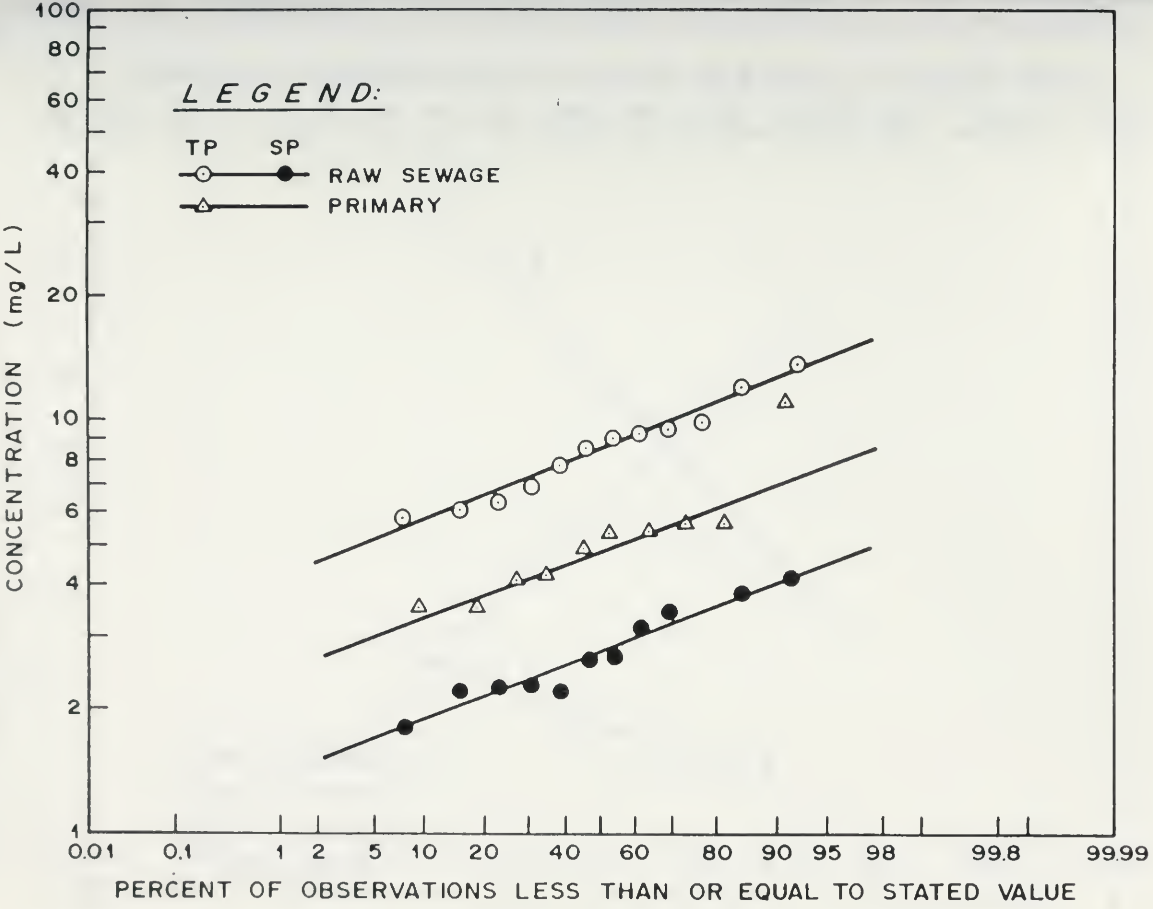


FIGURE 7-2: PROBABILITY DISTRIBUTIONS FOR RAW SEWAGE PHOSPHORUS AND PRIMARY EFFLUENT TOTAL PHOSPHORUS DATA AT THE HUMBER WPCP

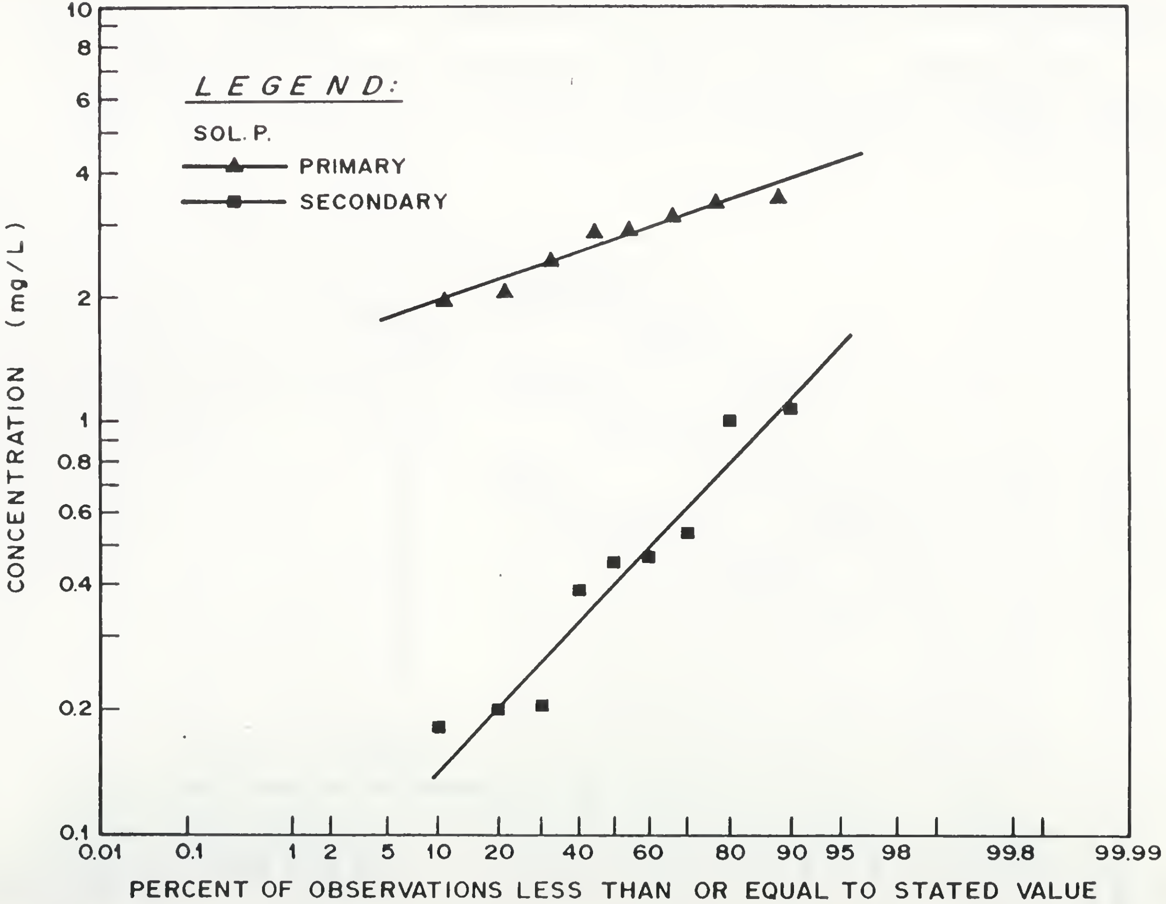


FIGURE 7-3: PROBABILITY DISTRIBUTIONS FOR PRIMARY AND SECONDARY EFFLUENT SOLUBLE PHOSPHORUS DATA AT THE HUMBER WPCP

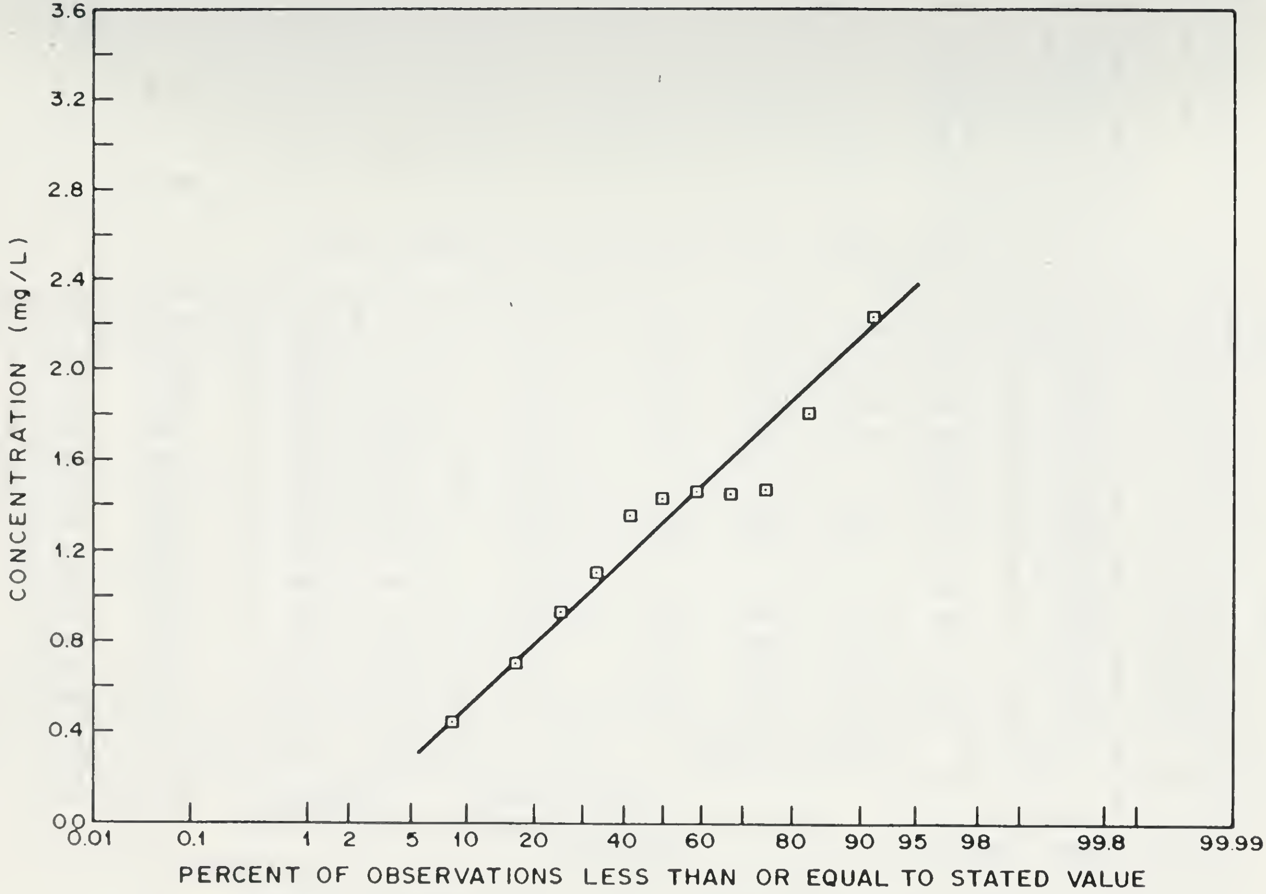


FIGURE 7-4: PROBABILITY DISTRIBUTIONS FOR SECONDARY EFFLUENT TOTAL PHOSPHORUS DATA AT THE HUMBER WPCP

TABLE 7.6. SUMMARY OF KEY OPERATING PARAMETERS FOR HUMBER WPCP

DATE	FLOW ($10^3 m^3/d$)		CLARIFIER LOAD ($m^3/m^2/d$)		Fe DOSE (mg/L)	PRIM CLAR SOLUBLE P (mg/L)	Fe:P RATIO*		EFFLUENT QUALITY (mg/L)			
	AVG.	PEAK	AVG.	PEAK			WEIGHT	MOLAR	TSS	TP	SOLUBLE P	PART P
Aug 6	486	705	26.7	38.7	5.13	3.40	1.51	0.84	25	1.1	0.47	0.63
10	323	486	17.7	26.7	7.51	2.90	2.59	1.44	17	<.45	<0.2	<.25
11	386	536	21.2	29.5	11.75	2.45	4.80	2.68	16	0.70	0.21	0.49
17	393	614	21.6	33.7	7.18	2.05	3.50	1.95	30	<.45	<0.18	<0.27
18	439	832	24.1	45.7	5.30				20	0.93	0.99	-
19	414	582	22.7	32.0	3.23	2.86	1.13	0.63	30	1.36	0.39	0.97
20	418	609	23.0	33.5	1.29	1.94	0.66	0.37	26	1.47	0.53	0.94
25	386	614	21.2	33.7	2.12	3.16	0.67	0.37	31	1.45		
26	459	1068	25.2	58.7	2.0				285	2.25	1.05	1.20
Sept 4	414	1119	22.7	61.5	6.92	3.45	2.01	1.21	50	1.46	0.46	1.00
5	500	659	27.5	36.2	3.64	2.90	1.26	0.70	90	1.81	0.53	1.28
6	368	605	20.2	33.2	9.90	2.90	3.41	1.90	40	1.44	<0.2	1.24
AVG.	**415.5**	**702.4**	**22.8**	**38.6**	**5.50**	**2.80**	**2.15**	**1.20**	**55**	**1.24**	**0.47**	**0.77**

Note: *Based on Primary Effluent Soluble Concentration tively high hydraulic loading in the final clarifiers. This problem is aggravated by high peak flows that result from the combined sewers feeding the plant. On August 26, 1986 a high peak flow caused by heavy rainfall, resulted in a final effluent suspended solids concentration of 285 mg/L. Sludge management problems may also contribute to the high final effluent suspended solids concentrations. As sludge disposal options for the plant are limited, a small volume of return activated sludge is wasted daily, thus resulting in the formation of a high sludge blanket in the final clarifiers. The sludge blanket may in part be responsible for the high suspended solids in the final effluent.

8.0 TORONTO MAIN WATER POLLUTION CONTROL PLANT

8.1 Plant Description and Historical Performance

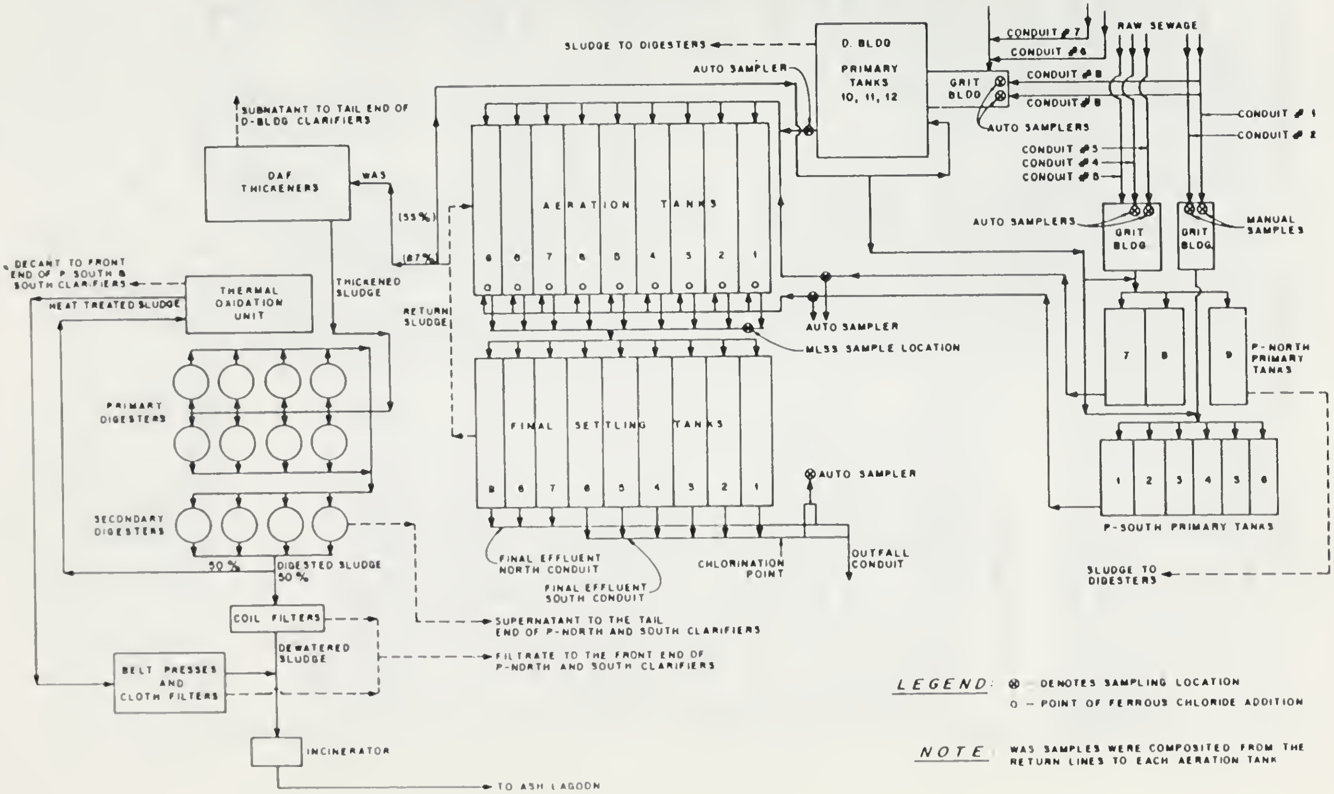
8.1.1 Plant Description

The Main WPCP is the largest of two major secondary treatment facilities serving Metropolitan Toronto. The plant which is operated by Metro Toronto is a conventional activated sludge plant designed to handle an average daily flow of 818,300 m^3/d (180 MIGPD) with a peak hydraulic flow of 1638,000 m^3/d (360 MIGPD). A schematic flow sheet of the plant is provided in Figure 8.1. Key design parameters for the Main plant are summarized in Table 8.1.

Raw sewage enters the plant via pumping stations except for raw sewage in the Coxwell trunk sewer that flows into the plant (conduits #3 and 4) by gravity. The pumping stations employ ten constant speed centrifugal pumps with a rated capacity of between 90,920 m^3/d and 181,800 m^3/day, as well as five variable speed centrifuge pumps rated at 272,760 m^3/d each. Nine conduits channel the raw sewage into the plant, each with a venturi meter for flow measurement. Screening in provided by twenty mechanically cleaned bar screens. Grit removal is accomplished with ten aerated units (D. Bldg. and P. North Bldg) with a design HRT of 12.5 min and six channels (P. South Bldg) with a design HRT of 25 min.

There are twelve primary clarifiers situated at three different locations on the site, three in D. Bldg., three at P. North and six at P. South. (see Figure 8.1). The D. Bldg. clarifiers are 36.5 m by 94.8 m, P. North clarifiers are 32.9 m by 76.2 m and the P. South clarifiers are 19.5 m by 61.0 m, thus providing a total surface area of 25,030 m^2. The total primary clarifier volume is approximately 111,900 m^3. Raw sludge and scum removal are accomplished by travelling bridge mechanisms for clarifiers 7 to 12 and by a wooden flight on endless chain and sprocket for clarifiers 1 to 6.

Biological treatment is accomplished in nine parallel aeration tanks. Each tank is 162 m by 24.4 m and has four channels. The total aeration volume is 158,500 m^3. Air is introduced into the cells through an air sparger diffused air system serviced by five compressors rated at 935 kW



LEGEND: ⊗ – DENOTES SAMPLING LOCATION
○ – POINT OF FERROUS CHLORIDE ADDITION

NOTE: WAS SAMPLES WERE COMPOSITED FROM THE RETURN LINES TO EACH AERATION TANK

FIGURE 8-1 : SCHEMATIC FLOWSHEET OF TORONTO MAIN WPCP

TABLE 8.1 - DESIGN SUMMARY - TORONTO MAIN WPCP

DESIGN CRITERIA	DESIGN VALUE	
	AVERAGE	PEAK
Flow (m^3/d)	818,300	1,638,000
Sewer Collection System	some combined	
Bypass - Point	After south primary tanks (#1-6)	
- Frequency	10/year	
- Discharge Point	Outfall	
Primary Clarification		
HRT (hours)	3.28	1.64
Surface Load ($m^3/m^2/d$)	55.5	124
Hydraulic Capacity (m^3/s)	15.7	35.7
Weir Loading Rate ($m^3/m/d$)	5,190	-
Aeration System		
HRT (hours)	4.65	2.32
BOD Loading Rate ($kg/m^3/d$)	0.89	-
Return Sludge Rate	100%	-
Phosphorus Removal		
Chemical	Ferrous Chloride	
Addition Point	Upstream of aeration tank overflow weir	
Secondary Clarification		
HRT (hours)	2.25	1.12
Surface Loading ($m^3/m^2/d$)	40.8	81.6
Chlorination	2.6 mg/L	
Dosage	Chlorine added to final effluent conduit (no contact tank)	

each, and three compressors rated at 2240 kW each. As there are the same number of final clarifiers as there are aeration tanks, return activated sludge from each clarifier is routed to the corresponding aeration tank.

Phosphorus removal is accomplished by ferrous chloride addition to the mixed liquor prior to the overflow weir of the aeration tanks. Ferrous chloride is pumped from eight storage tanks to the addition points. However, three to four tanks are utilized at a time, while the rest are being filled. The chemical feed rate is adjusted manually.

Secondary clarification is accomplished in nine parallel 24.4 m by 91.4 m rectangular clarifiers, providing a total surface area of 20,071 m^2 and a total liquid volume of 11,970 m^3. The sludge removal mechanisms are wooden flight on endless chain and sprocket. Return sludge is handled by centrifugal pumps which return the sludge from each clarifier to the corresponding aeration tank. The return pumps are capable of 100 percent sludge recycle. Secondary effluent is chlorinated prior to discharge to Lake Ontario.

Waste activated sludge is thickened in the dissolved air flotation unit. The total surface area available for thickening is 743 m^2. Two-stage anaerobic digestion is provided for the thickened waste activated sludge as well as primary sludge. Eight primary digesters and four secondary digesters provide a total volume of 89,200 m^3. Approximately 50 percent of the digested sludge undergoes heat treatment in the thermal oxidation unit. This unit can accept 1,309 m^3 sludge/d, and has a design temperature and pressure of 195°C and 2,200 kPa, respectively. Following heat treatment, the sludge is dewatered with belt presses and cloth filters. The remaining 50 percent of digested sludge that does not undergo heat treatment is dewatered using coil filters. All dewatered sludge is then incinerated, and the ash disposed in a lagoon on-site.

8.1.2 Historical Performance

Table 8.2 summarizes the annual performance of the Main WPCP for the years 1981 to 1985. Effluent quality showed a deteriorating trend over this time period, despite minimal changes in plant hydraulic loadings. The five year (1981 to 1985) effluent quality averages were 14.7 mg/L BOD_5, 15.1 mg/L suspended solids and 0.93 mg/L for total phosphorus. 1985 was the only

TABLE 8.2: ANNUAL AVERAGE PERFORMANCE OF MAIN WPCP

PARAMETER	YEAR					5 YEAR AVERAGE 81-85
	1981	1982	1983	1984	1985	
Average Daily Flow (1,000 m^3/d)	752.36	709.18	737.59	677.25	683.83	712.04
BOD_5 - Influent (mg/L)	197.80	206.80	224.00	215.42	167.00	202.20
BOD_5 - Effluent (mg/L)	7.10	11.60	13.20	19.33	22.33	14.71
TSS - Influent (mg/L)	204.30	227.90	260.00	228.25	195.67	233.22
TSS - Effluent (mg/L)	11.70	13.90	11.83	11.92	26.00	15.07
Total P - Influent (mg/L)	5.80	6.40	5.93	5.88	5.85	5.97
Total P - Effluent (mg/L)	0.80	0.91	0.89	0.97	1.09	0.93

year when the annual average total phosphorus concentration exceeded 1 mg/L. Influent strength was fairly typical (202 mg/L BOD_5, 223 mg/L suspended solids and 5.97 mg/L total phosphorus). Average daily flow to the plant for the five year period was 712,040 m^3/d (87.0 percent of design flow).

Monthly effluent quality data for 1984 and 1985 (BOD_5, suspended solids and total phosphorus) are presented in Table 8.3. Effluent phosphorus levels exceeded 1.0 mg/L for four months in 1984 and seven months in 1985. Effluent suspended solids exceeded 15 mg/L for two months in 1984 and for nine months in 1985. Effluent BOD_5 exceeded 15 mg/L for nine months in 1984 and ten months in 1985. In general, the effluent quality was better in 1984 than the effluent quality attained in 1985.

8.3 Sampling Program

The Main WPCP was sampled between August 6, 1986 and September 2, 1986. Twelve daily samples were collected over this monitoring period.

Sampling locations were identified in Figure 8.1. Twenty-four hour composite samples of raw wastewater were obtained (after screening for conduits 1 and 2), before screening for conduits 3 to 9) from the conduits in use. These samples were flow composited to obtain a single representative sample. Twenty-four hour composite samples of primary effluent were obtained from P. North, P. South and D. Bldg. clarifiers. These samples were flow composited to obtain a single representative sample. Flow-proportional 24-hour composite samples of secondary effluent (after chlorination) were collected. The samples were a 50/50 mix of effluent from the north and south final effluent conduits. In addition composite samples of mixed liquor and return sludge were collected to allow SRT calculations to be completed. Ferrous chloride samples were obtained from an air line on one of the chemical feed pumps. This sample was representative of iron salt added to the aeration headers as the pumps were fed from a common header.

8.4 Results of Sampling Program

Table 8.4 presents operating data for the sampling dates at the Main WPCP. Average daily flow for these dates was 1,262,000 m^3/d or 154 percent of plant design. This flow is significantly higher than observed during

TABLE 8.3 - MONTHLY AVERAGE PERFORMANCE OF MAIN WPCP

YEAR	MONTH	EFFLUENT BOD_5 (mg/L)	n BOD	EFFLUENT TSS (mg/L)	n TSS	EFFLUENT TP (mg/L)	n TP
1984	JAN.	29.0	21	13.0	30	1.20	30
	FEB.	18.0	21	18.0	29	1.20	29
	MAR.	9.0	21	12.0	31	0.80	31
	APR.	20.0	18	10.0	30	1.00	30
	MAY	26.0	19	20.0	30	1.00	30
	JUN.	17.0	17	11.0	30	0.60	29
	JUL.	17.0	21	8.0	31	0.70	30
	AUG.	12.0	17	9.0	29	1.10	28
	SEP.	8.0	20	6.0	30	0.80	30
	OCT.	19.0	20	13.0	31	0.90	30
	NOV.	25.0	21	15.0	30	1.40	29
	DEC	32.0	14	8.0	31	0.90	31
1985	JAN.	24.0	23	10.0	29	1.10	31
	FEB.	27.0	16	28.0	25	1.10	25
	MAR.	33.0	19	29.0	30	0.80	30
	APR.	11.0	19	12.0	30	0.60	29
	MAY	18.0	16	21.0	30	0.90	30
	JUN.	20.0	16	21.0	30	1.10	30
	JUL.	14.0	18	15.0	30	1.10	30
	AUG.	17.0	15	16.0	29	0.90	29
	SEP.	16.0	21	20.0	30	0.80	30
	OCT.	36.0	20	81.0	31	2.50	31
	NOV.	22.0	18	28.0	27	1.10	28
	DEC	30.0	17	31.0	27	1.10	25

n - Number of samples

TABLE 8.4 - SUMMARY OF MAIN WPCP OPERATING CONDITIONS

DATE (1986)	FLOW ($10^3 m^3/d$) TOTAL	MAX	BYPASS	MLSS (mg/L)	MLVSS (%)	RAS (mg/L)	RAS ($\times 10^3 m^3/d$)	WAS (m^3	$FeCl_2$ (L)	Fe DOSAGE (mg/L)	SRT (days)	COMMENT
Aug 6	1186	1317		5700	61.8	11640	258	33300	57738	4.4	1.5	7.6 mm rain
10	1250	1802		3680	62.5	8760	248	27100	54856	4.0	2.3	2.6 mm rain
11	1149	1786		3540	61.0	13380	-	27100	60439	4.7	1.5	trace of rain
12	1147	1700		4300	57.2	14300	284	32200	64407	4.7	1.5	
13	1013	1387		4680	57.3	17500	285	25900	54007	5.3	1.5	
17	1321	1826		2960	57.4	14600	258	27700	62734	3.9	1.1	heavy rain Aug 16
18	1373	1813		4520	56.2	16560	256	27800	56947	3.4		
20	1230	1645		3420	64.3	16100	238	32200	70890	4.7	1.0	
25	1090	1238		4840	56.6	14540	217	33800	59161	5.1	1.5	trace of rain
26	1297	2953	101.1	3960	60.1	16380	252	24500	53151	4.1	0.9	55.2 mm rain
27	1885	3204	320.0	2860	58.7	15537	26.4	6100	51683	2.5		high flows from C.S.
Sept 2	1207	1671		2600	65/4	12180	23.7	7100	61902	4.0	2.4	
AVERAGE	1262	1862		3922	59.9	14176	213.3	25400	59910	4.2	1.5	

1985 (712,040 m^3/d or 87 percent of design). The unusually heavy precipitation during the sampling period contributed to these high flows. Peak flows in excess of 1,638,000 m^3/d were observed on ten of the twelve sampling days.

The biological system was operated in a stable mode by constant wasting. Solids retention time (SRT) varied from 0.9 days to 2.4 days, averaging 1.5 days for the sampling period.

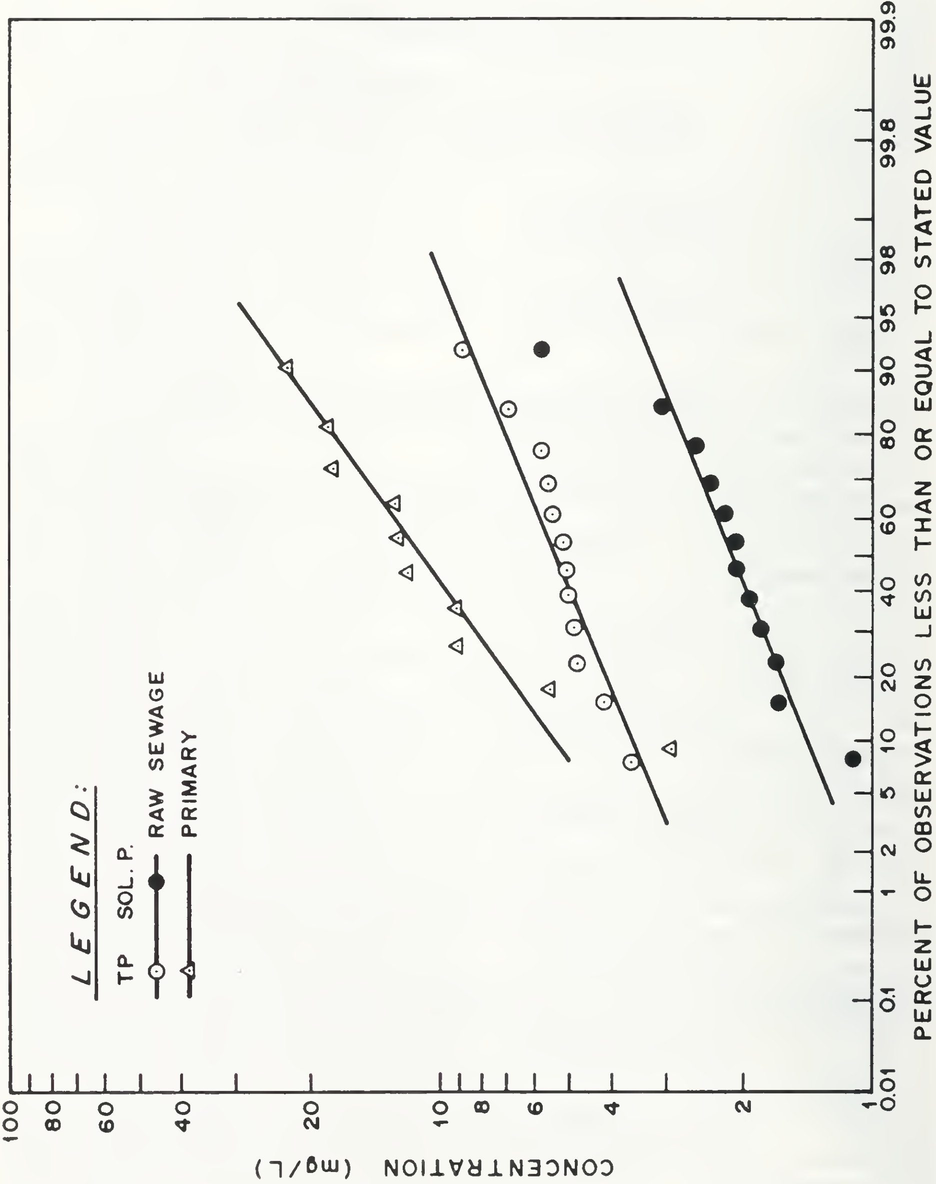
Ferrous chloride was added at a fairly constant rate during the monitoring period, averaging 59,910 L/d. The concentration of iron in the ferrous chloride varied from 51,683 mgFe/L to 70,890 mgFe/L. The calculated chemical dosage averaged 4.2 mgFe/L over the study period and ranged from 3.4 mg/L to 5.1 mg/L.

The results of the monitoring program are summarized in Table 8.5. Raw wastewater strength in terms of BOD_5 and suspended solids, was low compared to historical data. The raw wastewater averaged 87 mg/L BOD_5 and 177 mg/L suspended solids. Influent total phosphorus levels were slightly lower than indicated by historical data, averaging 5.5 mg/L. Approximately 43 percent of the total phosphorus was present in soluble form. The lower strength wastewater is consistent with the higher flows experienced during the monitoring period. Effluent quality during the monitoring period was markedly different from historical data. The average effluent BOD_5 was 5.7 mg/L as compared to the five year average (1981-1985) of 14.7 mg/L. This lower effluent BOD_5 was probably due to the lower influent BOD_5 levels observed. The average effluent suspended solids was 58 mg/L, more than three times the five year average of 15 mg/L. The high effluent suspended solids was a result of the unusually high rainfall during the sampling period. The total phosphorus in the final effluent was 2.01 mg/L, of which 13.4 percent was in soluble form. Probability distributions for the total and soluble components of the phosphorus in raw sewage, primary effluent and secondary effluent are presented in Figures 8.2 and 8.3. There was an increase in total phosphorus in the primary effluent caused by the in-plant recycle flows that are high in suspended solids.

Key operating parameters affecting phosphorus removal at the Main WPCP are summarized in Table 8.6. Average final clarifier loadings of approximately 63 $m^3/m^2/d$ were observed which were higher than the design rate of 40.8 $m^3/m^2/d$. Peak hydraulic loadings greater than the design peak loading of 81.6 $m^3/m^2/d$ were also observed on several occasions. This high

TABLE 8.5: SUMMARY OF PERFORMANCE MONITORING DATA FOR MAIN WPCP

		CONCENTRATION (mg/L)			
DATE	STREAM	BOD_5	TSS	TOTAL P	SOLUBLE P
Aug 6	Raw	85	140	4.8	1.98
	Primary Effluent	-	-	12.75	4.95
	Secondary Effluent	16	180	6.24	<0.45
Aug 10	Raw	85	200	5.20	1.86
	Primary Effluent	-	-	NA	3.00
	Secondary Effluent	3.1	24	0.50	<0.19
Aug 11	Raw	100	160	4.90	2.20
	Primary Effluent	-	-	18.20	2.35
	Secondary Effluent	3.7	10	<0.45	<0.45
Aug 12	Raw	167	260	6.90	2.09
	Primary Effluent	-	-		4.30
	Secondary Effluent	4.2	7	0.47	0.18
Aug 13	Raw	NA	NA	8.88	5.80
	Primary Effluent	-	-	23.20	3.85
	Secondary Effluent	5	40	1.11	0.21
Aug 17	Raw	65	130	5.10	1.67
	Primary Effluent	-	-	18.0	2.55
	Secondary Effluent	3	6	0.77	<0.45
Aug 18	Raw	80	130	4.18	1.65
	Primary Effluent	-	-	9.25	1.10
	Secondary Effluent	3	NA	0.47	<0.15
Aug 20	Raw	130	210	5.08	2.07
	Primary Effluent	-	-	5.6	2.85
	Secondary Effluent	3	36	1.45	0.18
Aug 25	Raw	48	270	5.44	3.07
	Primary Effluent	-	-	9.08	2.05
	Secondary Effluent	2	18	0.88	NA
Aug 26	Raw	35	130	5.56	2.40
	Primary Effluent	-	-	12.5	2.10
	Secondary Effluent	16	249	8.8	<0.30
Aug 27	Raw	42	200	3.62	1.13
	Primary Effluent	-	-	12.0	1.10
	Secondary Effluent	7	70	2.55	<0.23
Sept 2	Raw	120	220	5.80	2.55
	Primary Effluent	-	-	2.96	2.35
	Secondary Effluent	2	10	<0.45	<0.20
AVERAGE	Raw	87	177	5.5	2.37
	Primary Effluent	-	-	12.35	2.71
	Secondary Effluent	5.7	58.2	2.01	0.27


LEGEND:
TP
SOL. P.
RAW SEWAGE
PRIMARY
CONCENTRATION (mg/L)
100
80
60
40
20
10
8
6
4
2
1
0.01
0.1
1
2
5
10
20
40
60
80
90
95
98
99.8
99.99
PERCENT OF OBSERVATIONS LESS THAN OR EQUAL TO STATED VALUE

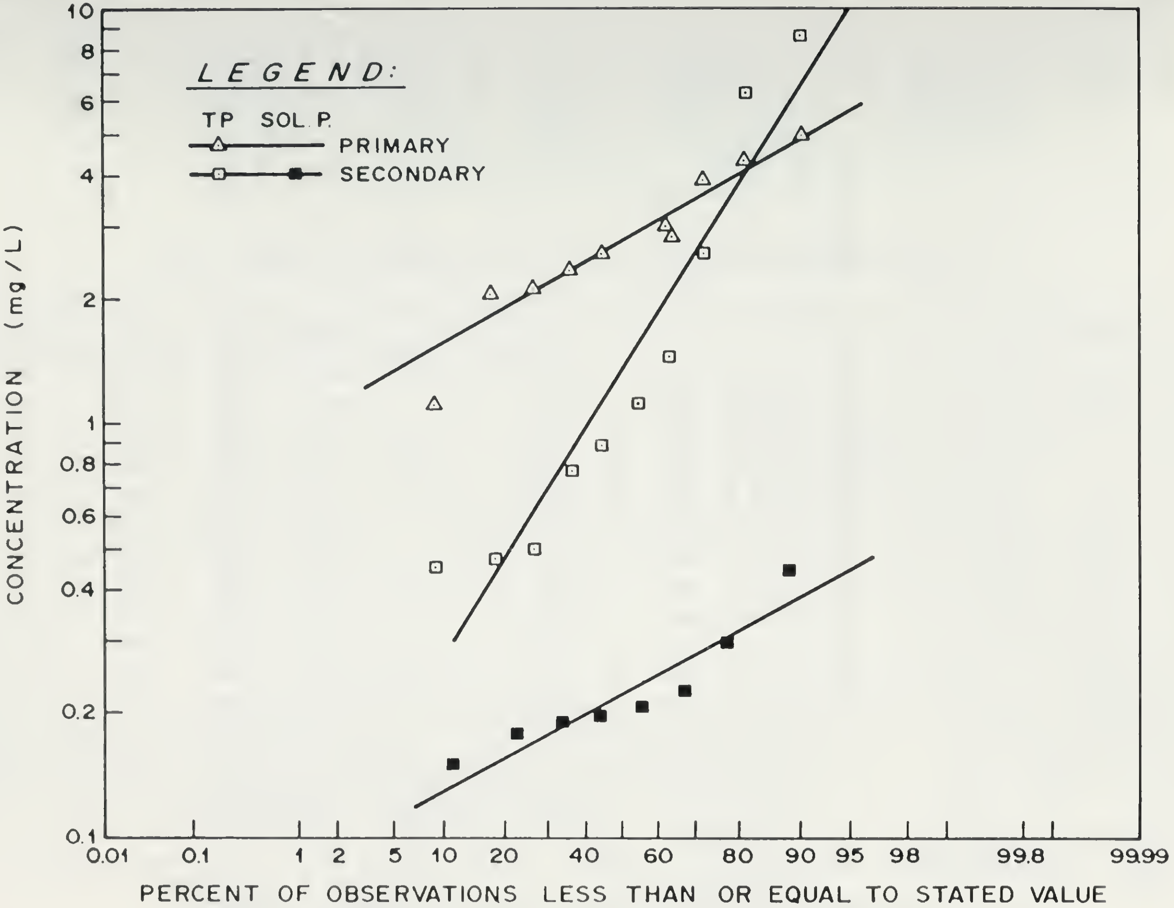


FIGURE 8-3: PROBABILITY DISTRIBUTIONS FOR PRIMARY EFFLUENT TOTAL PHOSPHORUS AND SECONDARY EFFLUENT TOTAL AND SOLUBLE PHOSPHORUS DATA AT THE MAIN WPCP

TABLE 8.6. SUMMARY OF KEY OPERATING PARAMETERS FOR MAIN WPCP

DATE	FLOW ($10^3 m^3/d$)		CLARIFIER LOAD ($m^3/m^2/d$)		Fe DOSE (mg/L)	PRIM CLAR SOLUBLE P (mg/L)	Fe:P RATIO*		EFFLUENT QUALITY (mg/L)			
	AVG.	PEAK	AVG.	PEAK			WEIGHT	MOLAR	TSS	TP	SOLUBLE P	PART P
Aug 6	1186	1317	58.9	65.6	4.4	4.95	0.88	0.59	180	6.24	<.45	5.79
10	1250	1802	62.3	89.8	4.0	3.00	1.34	0.74	14	0.5	<0.19	0.31
11	1149	1786	57.2	89.0	4.7	2.35	1.99	1.1	10	<.45	<.45	-
12	1147	1700	57.1	84.7	4.7	4.30	1.09	0.61	7	0.47	0.18	0.29
13	1013	1387	50.5	69.1	5.3	3.85	1.38	0.7	40	1.11	0.21	0.90
17	1321	1826	65.8	91.0	3.9	2.55	1.55	0.86	6	0.77	<.45	0.32
18	1373	1813	68.4	90.3	3.4	1.10	3.13	1.75	-	0.47	<0.15	0.32
20	1230	1645	61.3	82.0	4.7	2.85	1.65	0.92	36	1.45	0.18	1.27
25	1090	1238	54.3	61.7	5.1	2.05	2.49	1.39	18	0.88	-	-
26	1297	2953	64.6	147.1	4.1	2.10	1.95	1.09	249	8.8	<0.3	8.5
27	1885	3204	93.9	159.6	2.5	1.10	2.28	1.27	70	2.55	<0.23	2.32
Sept 2	1207	1671	60.1	83.3	4.0	2.5	1.70	0.95	10	<.45	<0.20	0.25
AVG.	**1262**	**1862**	**62.9**	**92.8**	**4.2**	**2.71**	**1.79**	**1.0**	**58**	**2.01**	**<0.27**	**1.74**

Note: *Based on Primary Effluent Soluble Phosphorus Concentrations loading contributed to the high final effluent suspended solids concentrations. This was reflected in the high effluent phosphorus concentrations associated with particulate matter, approximately 87 percent.

Based on soluble phosphorus in the primary effluent, the average Fe:P molar ratio was 1.0 which is the stoichiometric requirement. The chemical dosage averaged 4.2 mg Fe/L over the monitoring period and ranged from 2.5 mg Fe/L to 5.3 mg Fe/L. The resulting final effluent soluble phosphorus concentrations were relatively low and averaged 0.27 mg/L.

8.3 Conclusions of the Main WPCP Monitoring Program

The final effluent total phosphorus levels over the monitoring period were much higher than historically reported. The final effluent BOD5 levels were lower and the suspended solids levels higher than historically reported. Raw wastewater strength was lower than had been reported due to unusually high rainfalls.

The soluble phosphorus component of the total phosphorus in the final effluent was relatively low. The removal of soluble phosphorus with the addition of ferrous chloride seems to be working effectively.

Phosphorus contained in particulate form constituted a large component of total phosphorus in the final effluent. This was probably a result of a loss of suspended solids with the final effluent, caused by high hydraulic loadings in the final clarifiers. This problem is magnified during a heavy rainfall whereby a peak flow of a much larger duration is encountered. These peak flows are a result of combined sewers that feed the plant. On August 26, 1986 a high peak flow caused by heavy rainfall resulted in a final effluent suspended solids of 249 mg/L and a total phosphorus concentration of 8.8 mg/L, of which approximately 97 percent was in particulate form.

9.0 DUFFIN CREEK WATER POLLUTION CONTROL PLANT

9.1 Plant Description and Historical Performance

9.1.1 Plant Description

The Duffin Creek WPCP is a conventional activated sludge plant located in Pickering, near the mouth of the Duffin Creek. The plant, which is operated by the Regional Municipality of Durham, is the first stage in a four-stage facility which will eventually serve over 800,000 people connected to 112 km (70 mi.) of trunk sewer in the Regions of Durham and York. The completed first stage (hereinafter referred to as the Duffin Creek WPCP or plant) has an average daily capacity of 189,250 m^3/d (104.1 MIGD). Figure 9.1 presents a schematic diagram of the plant. Key design information for the Duffin Creek WPCP is presented in Table 9.1.

Raw sewage enters the treatment facility at the splitting chamber at the head of the plant. From there, the sewage flows to a lift station where 3 screws pumps (3.2 m diameter) elevate the sewage so that it can flow through the remainder of the plant via gravity.

Preliminary treatment consists of screening and grit removal. Six mechanically cleaned, hydraulically operated screens, each 1.83 m wide, are used to remove screenable material from the influent sewage. Four 10.7 m square detritor tanks, each 0.8 m deep, are employed for grit removal. All screenings and grit removal during preliminary treatment are disposed of in landfill sites.

Effluent from the detritor tanks is split approximately evenly between the east and west sides of the plant. Four primary clarifiers, each 24.4 m x 54.0 m x 3.7 m, provide a total surface area of over 5270 m^2 for primary sedimentation. Total primary clarifier volume is about 19,500 m^3. Settled raw sewage and surface scum are removed by travelling-bridge mechanisms. Sludge and scum removed from the primary clarifiers is pumped to either the primary digester or directly to the belt filter presses.

Biological treatment of the Duffin Creek WPCP involves aeration of the effluent from the primary clarifiers for 6.4 hours. Four basins, each containing four cells (total of 16 cells), are employed. The aeration cells are 22.9 m square and 5.8 m deep. The total volume available for aeration is 48,665 m^3. Oxygen transfer is accomplished by 75 kW mechanical surface aerators.

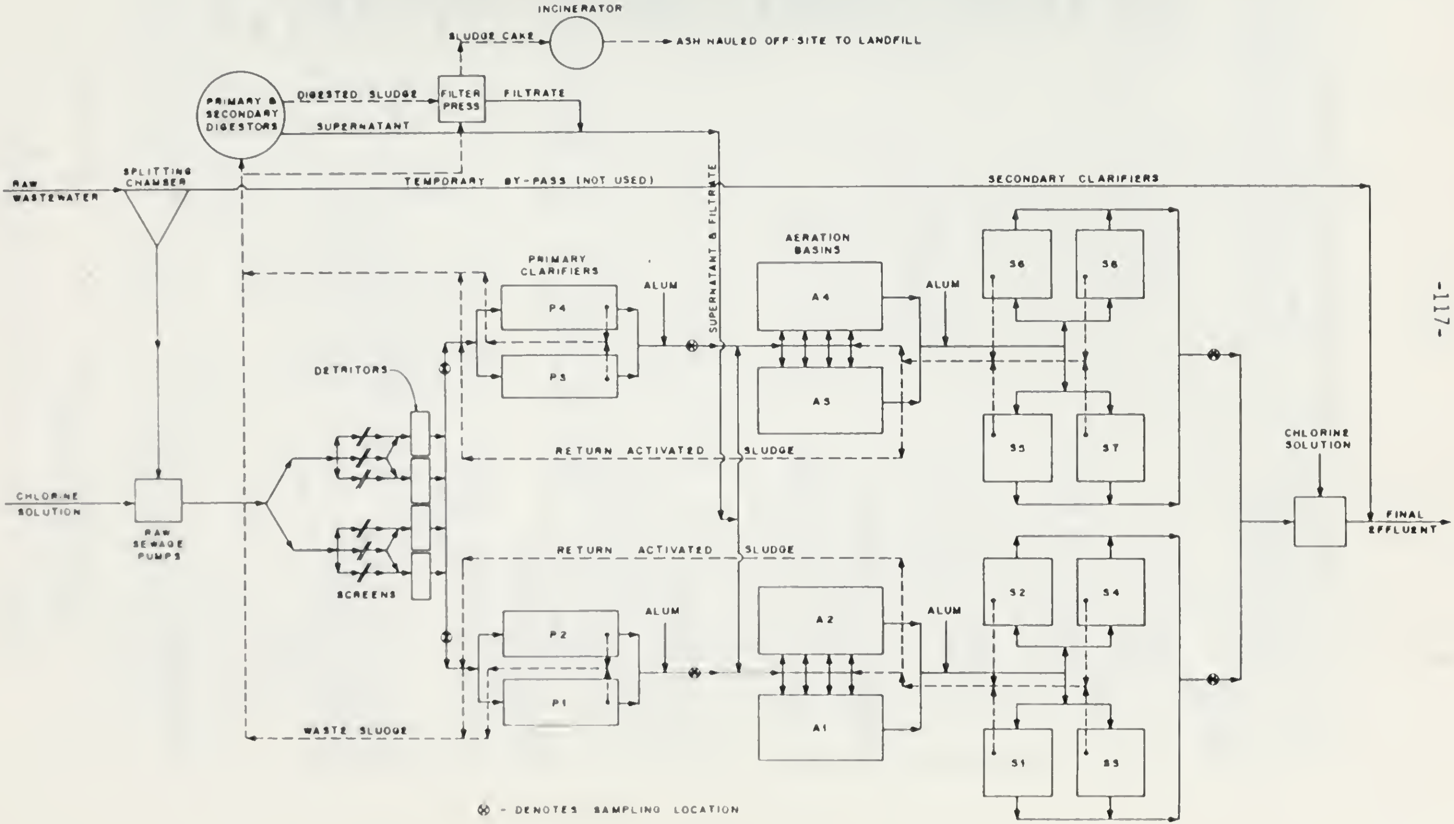


FIGURE 9-1 PROCESS FLOW SCHEMATIC OF DUFFIN CREEK WPCP

TABLE 9.1 - DESIGN SUMMARY - DUFFIN CREEK WPCP

DESIGN CRITERIA	DESIGN VALUE	OPERATING LEVEL(1)
General		
Flow (m^3/d)		
Average Daily	189,250	97,530
Peak	473,125	est 292,000(2)
BOD_5		
Concentration (mg/L)	240	165
Loading (kg/d)	-	16,092
TSS		
Concentration (mg/L)	270	244
Loading (kg/d)	-	23,797
Sewage Collection System	100% separate	
Primary Clarification		
HRT (hours)	3.0	5.8
Average Surface Loading ($m^3/m^2 \cdot d$)	35.9	18.5
Peak Surface Loading ($m^3/m^2 \cdot d$)	89.8	55.4
Aeration System		
HRT (hours)	6.4	12.4
BOD_5 Loading ($g/m^3 \cdot d$)	641	337
Maximum Return Sludge Rate (%)	100	-
Phosphorus Removal		
Chemical	Alum	-
Average Dosage (mgAl/L)		
- 1984	-	3.4
- 1985	-	3.6
Secondary Clarifiers		
HRT (hours)	5.14	10.0
Average Surface Loading ($m^3/m^2 \cdot d$)	17.8	9.2
Peak Surface Loading ($m^3/m^2 \cdot d$)	44.6	27.5
Chlorination		
HRT (min) @ Average Flow	5.0	9.7

Notes: (1) Information shown based on 1981 - 1985 historical data except as noted.

(2) Based on daily flow records for August 1986.

Alum is added to the effluent from both the primary clarifiers and the aeration basins for phosphorus removal. About 10 to 20 percent of the total alum is added after primary clarification. The remainder (80 to 90 percent) is added to the aeration basins. The alum is metered into the wastewater at a rate of about 8 L/min (2.11 Igpm).

Secondary clarification of the mixed liquor from the aeration basin is accomplished in eight circular basins, each 41.1 m in diameter and 3.7 m deep. The total surface area and volume provided by the secondary clarifiers are approximately 10,610 m^2 and 39,270 m^3, respectively. Sludge is removed from the bottom of the secondary clarifiers by scrapers, through a hopper at the centre of the tank. Four 1.7 m screw pumps, each with a capacity of 47,310 m^3/d, return the activated sludge back to the head of the aeration tanks or waste it at the head of the primary tanks.

Overflow from the secondary clarifiers is disinfected via chlorination for 5 min. (at average daily design flow) in a 22.3 m x 9.1 m x 3.7 m contact chamber. The chlorinated effluent is discharged to Lake Ontario through a 3 m diameter outfall, 1.1 km off shore.

Waste sludge from the primary clarifiers is pumped to either one of two primary digesters or to the belt filter press for further treatment.

Sludge treatment prior to dewatering is accomplished by two-stage digestion. Two primary and two secondary digesters, each 33.5 m in diameter, 9.1 m deep, providing 807 m^3, are used. The primary digesters have fixed steel roofs, while the secondary digesters are equipped with floating gasholder covers.

Six belt filter presses, each with 1.0 m belts, are used to dewater the digested and waste sludges. The dewatered sludge cake is transferred to the fluid bed incinerators by a screw conveyor system.

Supernatant from the digesters along with filtrate from the belt presses is pumped to the head of the aeration tanks. Incinerated sludge ash is hauled to landfill sites for final disposal.

9.1.2 Historical Performance

Table 9.2 provides a summary of the annual performance for the Duffin Creek WPCP for 1981 through 1985.

TABLE 9.2: ANNUAL AVERAGE PERFORMANCE OF DUFFIN CREEK WPCP

PARAMETER	YEAR					5 YEAR AVERAGE 81-85
	1981	1982	1983	1984	1985	
Average Daily Flow (1,000 m^3/d)	41.37	84.51	95.12	121.13	149.87	97.53
BOD_5 - Influent (mg/L)	200.5	124.1	194.0	159.9	144.2	164.9
BOD_5 - Effluent (mg/L)	14.9	14.1	22.5	12.8	14.3	15.7
TSS - Influent (mg/L)	246.0	183.6	288.0	252.8	251.3	244.2
TSS - Effluent (mg/L)	18.0	12.2	25.2	15.9	15.9	17.5
Total P - Influent (mg/L)	7.00	7.01	8.08	7.19	6.05	7.08
Total P - Effluent (mg/L)	0.98	1.75	1.73	0.98	1.03	1.30

The 5-year average BOD_5 effluent concentration was 15.7 mg/L; however, with the exception of 1983, the annual average effluent BOD_5 level was less than 15 mg/L. The annual average effluent TSS concentrations were consistently above 15 mg/L, except in 1982. The 5-year average effluent TSS concentrations was calculated to be 17.5 mg/L. The level of total phosphorus discharged in the effluent from the plant has also been typically high. Average annual total P concentrations in the effluent have exceeded 1 mg/L for 3 of the last 5 years. The 5-year average effluent total phosphorus concentration was 1.30 mg/L. Influent for the past 5 years has been of relatively high strength (164.9 mg/L BOD_5, 244.2 mg/L TSS, and 7.08 mg/L total phosphorus). The average daily flow to the plant for the 1981 - 1985 period was 95,530 m^3/d, or about 52% of the design capacity.

Monthly effluent BOD_5, TSS and Total P concentrations for 1984 and 1985 are presented in Table 9.3. Effluent BOD_5 concentrations exceeded 15 mg/L for 8 of the 24 months, with the maximum level being 22.0 mg/L (June, 1985). TSS in effluent from the plant exceeded 15 mg/L for 10 of the 24 months. The highest monthly average effluent TSS concentration observed between 1984 and 1985 was 34.0 mg/L (April, 1984).

Total phosphorus levels in effluent from the Duffin Creek WPCP exceeded 1.0 mg/L for 12 of the 24 months. The highest monthly average effluent total P concentration was 1.4 mg/L, observed during 3 months in 1985 (January, April and June).

9.1.3 Sampling Program

The Duffin Creek WPCP was sampled on twelve days between August 5 and September 3, 1986. Twenty-four hour composite samples of raw sewage (downstream of detritors) and primary effluent were collected. Twenty-four hour flow proportional samples of effluent from the secondary clarifiers (prior to chlorination) were also collected. The sampling locations for these twenty-four hour samples were shown in Figure 9.1. Both the east and west sides of the plant were sampled separately.

In addition, grab samples of mixed liquor and return/waste activated sludge were collected in order to calculate solids retention times (SRTs).

TABLE 9.3 - MONTHLY AVERAGE PERFORMANCE OF DUFFIN CREEK WPCP

YEAR	MONTH	EFFLUENT BOD$_5$ (mg/L)	n BOD	EFFLUENT TSS (mg/L)	n TSS	EFFLUENT TP (mg/L)	n TP
1984	JAN.	20.3	16	15.8	28	1.10	21
	FEB.	17.5	12	17.1	22	1.00	18
	MAR.	14.6	12	15.3	22	0.80	13
	APR.	20.6	7	34.0	17	1.20	13
	MAY	13.8	9	11.8	18	0.70	10
	JUN.	9.5	8	17.0	20	0.90	9
	JUL.	12.8	10	13.7	20	0.90	11
	AUG.	11.5	15	17.5	20	1.20	11
	SEP.	8.2	11	10.6	19	0.90	11
	OCT.	9.6	13	12.3	20	0.90	11
	NOV.	9.1	11	11.5	20	1.10	12
	DEC	6.2	5	14.4	15	1.00	6
1985	JAN.	12.7	8	14.7	8	1.40	9
	FEB.	17.4	10	21.7	17	0.90	7
	MAR.	16.8	9	24.4	17	1.30	8
	APR.	18.6	10	18.7	20	1.40	9
	MAY	14.6	10	19.3	21	1.00	11
	JUN.	22.0	2	14.4	18	1.40	13
	JUL.	6.8	3	10.2	19	0.50	12
	AUG.	11.9	5	13.2	19	0.80	11
	SEP.	4.3	1	12.5	20	1.00	13
	OCT.	12.0	1	12.4	22	0.80	13
	NOV.	20.0	1	12.8	19	0.80	12
	DEC	-	-	-	-	-	-

n - Number of samples

9.2 Results of Sampling Program

Table 9.4 presents a compilation of plant operating data, supported by data collected by CANVIRO, for the month long sampling period at the Duffin Creek WPCP.

The average daily flow during this period was 186,900 m^3/d, equivalent to over 98% of the average design capacity. The average daily flow observed during the monitoring period was approximately 25% higher than the average daily flow through the plant during 1985 (149,870 m^3/d). The maximum flow observed during the monitoring period was almost 292,000 m^3/d, which was observed on August 27; total rainfall volume for that day was high (75.4 mm). All flows were less than the peak capacity for the plant (473,125 m^3/d).

The biological systems for both the east and west sides of the plant were operated in a relatively stable mode by constant sludge wasting. The average SRTs for the west and east sides of the plant were 3.6 days and 2.9 days, respectively. It should be noted that, according to plant personnel, the wasting rate shown for August of 4094 m^3/d may be too high.

Alum was added to the wastewater at a constant rate of 11,250 L/d (5,625 L/d to each side of the plant). Based on alum samples collected during the monitoring period, an average aluminum content of 43.4 g Al/L of alum was calculated. The chemical dosage, as aluminum, averaged 2.8 mg Al/L, and ranged from 1.7 mg Al/L during high flows, up to 3.2 mg Al/L for flows less than 160,000 m^3/d.

Table 9.5 presents the results of the sampling program undertaken at the Duffin Creek WPCP. Raw sewage quality during the monitoring period was comparable to historical influent quality, with the exception of BOD_5 (see Table 8.2). The 5-year annual average BOD_5 concentration in raw sewage was calculated to be almost 165 mg/L. BOD_5 levels in raw sewage entering the west and east plants during the monitoring period were 92.8 mg/L and 103.4 mg/L, respectively, representing a decrease of about 60% based on the 5-year annual average. Average total suspended solids concentrations in sewage influent to the west and east plants were 222.7 mg/L and 246.1 mg/L respectively. Average total phosphorus levels were 6.24 mg/L and 7.86 mg/L in raw sewage entering the west and east sides of the plant, respectively. Average

TABLE 9.4 - SUMMARY OF DUFFIN CREEK OPERATING CONDITIONS

(AUGUST 5 - SEPTEMBER 3, 1986)

DATE (1986)	FLOW	WEST(1)							EAST(2)							ALUM (L)	Al DOSE(3) (mg/L)	SRT		COMMENTS(4)
		MLSS (mg/L)	MLVSS (%)	RAS (mg/L)	WAS (m³)	BOD$_{in}$ (mg/L)	F/M	SVI (mL/g)	MLSS (mg/L)	MLVSS (%)	RAS (mg/L)	WAS (m³)	BOD$_{in}$ (mg/L)	F/M	SVI (mL/g)			WEST (d)	EAST (d)	
Aug 5	157,420	2,084	62	4,280(5)	4,094	-	-	53	1,513	63	2,880(5)	4,094	-		37	11,520	3.2	2.7	2.7	rain - 0.2 mm
6	155,400	2,323	64	4140	4,094	68	0.15	46	1,484	66	2,738	4,094	58	0.19	44	11,520	3.2	3.1	2.7	rain - 7.4 mm
7	182,020	2,103	63	4,440(5)	4,094	52	0.15	43	2,436	64	2,880(5)	4,094	71	0.29	42	11,520	2.7	2.5	2.3	rain - 6.6 mm
8	190,450	2,550	61	4,262	4,094	119	0.30	50	1,447	62	2,800	4,094	132	0.58	46	11,520	2.6	3.2	2.6	
11	161,550	3,665	59	5,060(5)	4,094	-	-	41	1,464	49	2,000(5)	4,094	-	-	41	11,520	3.1	4.2	3.4	
12	158,440	3,404	58	4,964	4,094	-	-	40	1,164	63	2010	4,094	-	-	43	11,520	3.2	3.8	2.5	
13	155,300	2,940	59	4,440(5)	4,094	86	0.16	42	1,064	63	1,512	4,094	71	0.34	43	11,520	3.2	3.6	2.6	
14	154,420	2,055	60	3,260	4,094	80	0.21	42	1,253	66	2,382	4,094	70	0.27	40	11,520	3.2	3.3	2.4	
15	261,640	2,999	63	5,290	4,094	68.3	0.20	42	1,418	66	3,064	4,094	44.6	0.26	43	11,520	1.9	2.9	2.1	
18	180,330	3,433	50	6,426	4,094	-	-	34	3,037	46	6,638	4,094	-	-	28	11,520	2.8	3.0	2.6	
19	178,300	2,790	50	-	4,094	-	-	36	2,850	47	-	4,094	-	-	32	11,520	2.8	-	-	
20	156,040	3,241	52	6,308	4,094	97	0.19	36	2,723	47	4,704	4,094	-	-	36	11,520	3.2	2.9	-	
21	162,910	2,862	50	-	4,094	64	0.15	39	2,214	51	-	4,094	65	0.20	32	11,520	3.1	-	-	
22	166,450	3,065	56	5,208	4,094	103	0.22	34	1,845	51	3,880	4,094	95	0.35	33	11,520	3.0	3.3	2.5	
25	162,410	3,294	54	5,798	4,094	-	-	35	1,998	53	3,964	4,094	-	-	30	11,520	3.1	3.2	2.7	rain overnight (25-26) - 0.2 mm
26	246,440	3,375	54	5,894	4,094	-	-	40	1,994	53	4,164	4,094	-	-	30	11,520	2.0	3.1	2.4	
27(5)	291,870	-	-	-	4,094	-	-	-	7,840	36	16,540	4,094	-	-	-	11,520	1.7	-	2.5	rain - 75.4 mm
28(5)	223,940	9,320	39	17,060	4,094	-	-	-	7,580	36	21,820	4,094	-	-	-	11,520	2.1	3.0	2.0	rain - 0.4 mm
29	195,880	8,600	41	19,810	4,094	-	-	28	7,310	38	20,086	4,094	-	-	26	11,520	2.6	2.4	2.0	
Sept 2	215,900(6)	5,802	43	12,230	1,307	-	-	23	5,372	40	11,720	1,307	-	-	30	11,520	2.3	7.6	6.4	
3	167,640	6,068	44	13,604	4,094	-	-	34	5,120	38	12,392	4,094	-	-	36	11,520	3.0	7.7	6.7	
AVERAGE	186,900	3,801	54.1	7,359	-	81.9	0.19	39.4	2,958	52.7	6,745	-	75.8	0.31	36.3	-	2.8	3.6	2.9	
MAXIMUM	291,870	9,320	64	19,810	-	119	0.30	53	7,840	66	21,820	-	132	0.58	46	-	3.2	7.7	6.7	
MINIMUM	154,420	2,055	39	3,260	-	52	0.15	28	1,064	36	1,512	-	44.6	0.19	26	-	1.7	2.4	2.0	

Notes (1)average of plant operating data for the two West basins

(2)average of plant operating data for the two East basins

(3)average concentration of AL in alum = 43.4 gAl/L

(4)information obtained from Environment Canada for rain gauge located in Oshawa

(5)data obtained by CANVIRO

(6)estimated

TABLE 9.5: SUMMARY OF PERFORMANCE MONITORING DATA FOR DUFFIN CREEK WPCP

		WEST CONCENTRATION (mg/L)				EAST CONCENTRATION (mg/L)			
DATE	STREAM	BOD_5	TSS	TOTAL P	SOLUBLE P	BOD_5	TSS	TOTAL P	SOLUBLE P
Aug 5	Raw	195	260	3.20	3.77	105	220	8.00	3.87
	Primary Effluent	-	-	5.00	3.00	-	-	4.60	3.15
	Secondary Effluent	3.2	8.0	0.64	0.41	3.7	15.0	1.60	0.83
Aug 6	Raw	118	230	7.00	2.79	98	120	6.13	2.60
	Primary Effluent	-	-	8.34	2.86	-	-	6.07	2.85
	Secondary Effluent	6.0	9.0	0.69	0.60	3.2	14.0	1.62	0.96
Aug 7	Raw	78	240	7.13	3.19	118	380	12.12	8.27
	Primary Effluent	-	-	8.20	1.63	-	-	6.76	3.70
	Secondary Effluent	6.0	6.0	0.73	0.45	6.0	11.0	1.55	1.06
Aug 11	Raw	73	160	6.40	3.24	92	240	6.43	3.80
	Primary Effluent	-	-	5.24	2.69	-	-	5.61	2.84
	Secondary Effluent	3.4	6.0	0.97	0.72	3.1	14.0	2.20	1.45
Aug 12	Raw	107	190	7.40	3.19	170	400	10.58	3.33
	Primary Effluent	-	-	11.10	2.15	-	-	6.40	3.00
	Secondary Effluent	3.0	7.0	1.96	0.79	7.0	21.0	2.50	1.42
Aug 13	Raw	50	113	6.24	3.45	130	187	10.42	3.25
	Primary Effluent	-	-	7.20	3.70	-	-	5.20	3.20
	Secondary Effluent	6.0	10.0	1.00	0.54	6.0	12.0	2.35	0.79
Aug 18	Raw	58	370	7.40	2.60	-	-	-	-
	Primary Effluent	-	-	4.45	2.35	-	-	9.80	2.11
	Secondary Effluent	6.0	9.0	0.88	0.53	6.0	5.0	0.74	0.72
Aug 25	Raw	130	200	-	2.79	121	180	-	2.79
	Primary Effluent	-	-	-	2.35	-	-	-	2.35
	Secondary Effluent	-	7.0	-	0.58	2.5	9.0	-	0.85
Aug 27	Raw	36	210	3.15	1.18	31	400	1.25	1.20
	Primary Effluent	-	-	5.56	1.08	-	-	2.15	1.20
	Secondary Effluent	11.0	19.0	1.07	0.45	16.0	26.0	0.91	0.48
Aug 28	Raw	59	220	5.30	1.05	52	210	8.00	1.73
	Primary Effluent	-	-	4.60	2.28	-	-	11.60	2.71
	Secondary Effluent	12.0	25.0	1.46	0.45	10.0	22.0	0.99	0.53
Sept 2	Raw	130	320	3.62	3.07	100	160	7.47	2.95
	Primary Effluent	-	-	5.82	2.10	-	-	5.20	2.70
	Secondary Effluent	6.0	4.0	1.15	0.88	6.0	4.0	0.53	0.48
Sept 3	Raw	80	160	6.80	-	120	210	8.20	2.53
	Primary Effluent	-	-	7.20	2.25	-	-	5.47	2.05
	Secondary Effluent	6.0	18.0	0.75	0.52	6.0	8.0	-	0.88
AVERAGE	Raw	92.8	222.7	6.24	2.6	103.4	246.1	7.86	2.85
	Primary Effluent	-	-	6.61	2.37	-	-	6.26	2.65
	Secondary Effluent	6.2	10.7	1.03	0.58	6.3	13.4	1.50	0.87

soluble phosphorus concentrations measured in the raw sewage were 2.76 mg/L and 2.65 mg/L, for the west and east sides of the plant, respectively; these represent 44% and 36% of total phosphorus levels.

Effluent quality, in terms of BOD_5 and TSS, during the monitoring period appeared to be high in comparison to the historical data shown in Tables 9.2 and 9.3. Average levels of BOD_5 in the secondary effluent from both sides of the plant were less than 6.3 mg/L; the highest effluent BOD_5 concentration was 16.0 mg/L recorded on August 27, which coincided with the large rainfall event. Average TSS concentrations in secondary effluent were 10.67 mg/L and 13.42 mg/L for the west and east sides of the plant, respectively. The highest TSS level in secondary effluent was also recorded on August 27. Average total phosphorus levels in the secondary effluents exceeded 1.00 mg/L. The proportion of soluble phosphorus in total phosphorus increased to approximately 60%. Probability distributions for the total and soluble components of phosphorus in raw sewage, primary effluent and secondary effluent are presented in Figure 9.2. Total phosphorus removal in the east primaries was only 20%, of which 35% was soluble. The average total phosphorus concentration in the west primaries was actually higher than that in the raw sewage.

Chemical precipitation resulted in removal of 84% of total phosphorus and 57% of soluble phosphorus in secondary clarifiers on the west side of the plant. Total soluble phosphorus removals for the east side of the plant, after chemical addition, were 76% and 67%, respectively.

Key operating parameters affecting phosphorus removal at the Duffin Creek WPCP are presented in Table 9.6.

Loadings to the secondary clarifiers are relatively low (17.4 $m^3/m^2 \cdot d$) even at peak flow (22.4 $m^3/m^2 \cdot d$). The low hydraulic loading coupled with good settleability, as indicated by the low values for SVI (see Table 8.4) should produce low suspended solids concentrations in the secondary effluent. This appears to be true for the west side of the plant, for which the secondary effluent TSS concentration averaged 10.7 mg/L (see Table 9.5). For the east side of the plant, the average TSS concentration in the secondary effluent was 13.4 mg/L, based on the twelve samples analyzed. Further, effluent TSS concentrations exceeded 15 mg/L with greater frequency on the east side of the plant in comparison to the west side. As shown in Table 9.5, although the influent flow to the plant is split evenly between

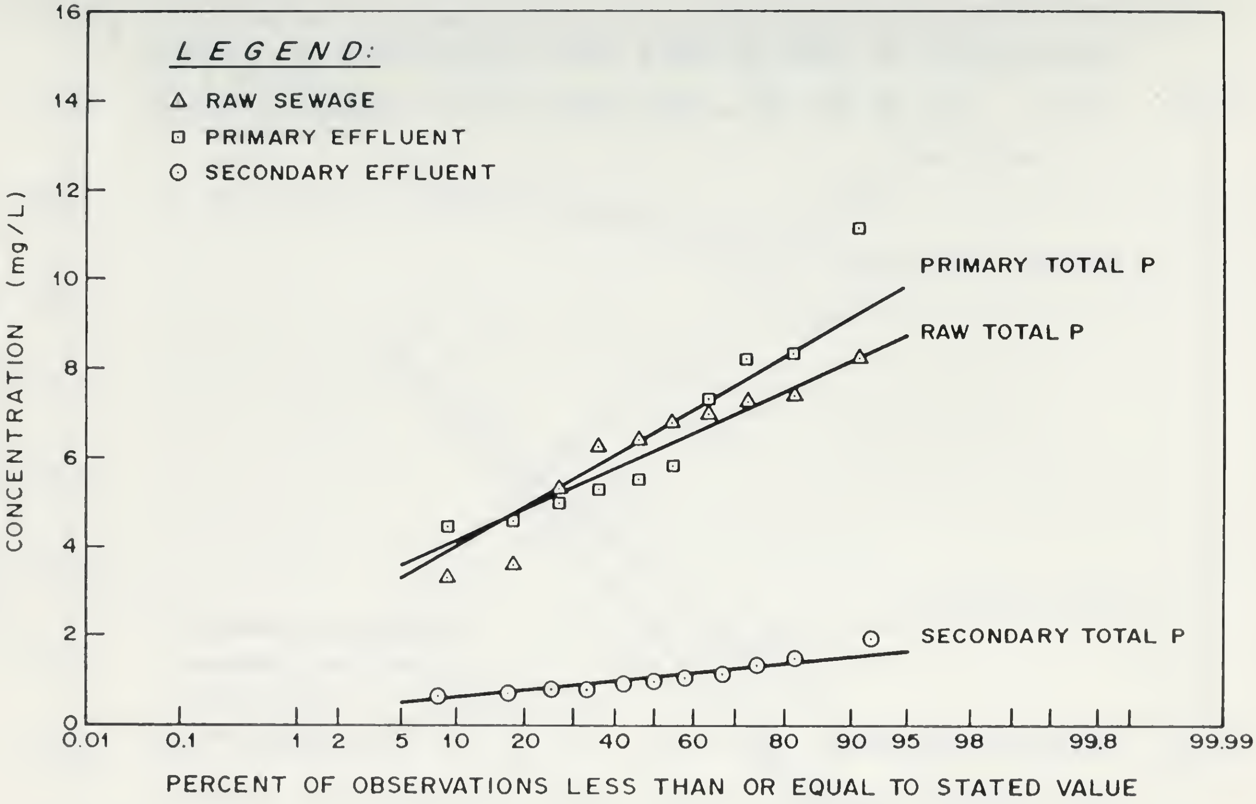


FIGURE 9-2: PROBABILITY DISTRIBUTIONS FOR PHOSPHORUS DATA AT DUFFIN CREEK WPCP

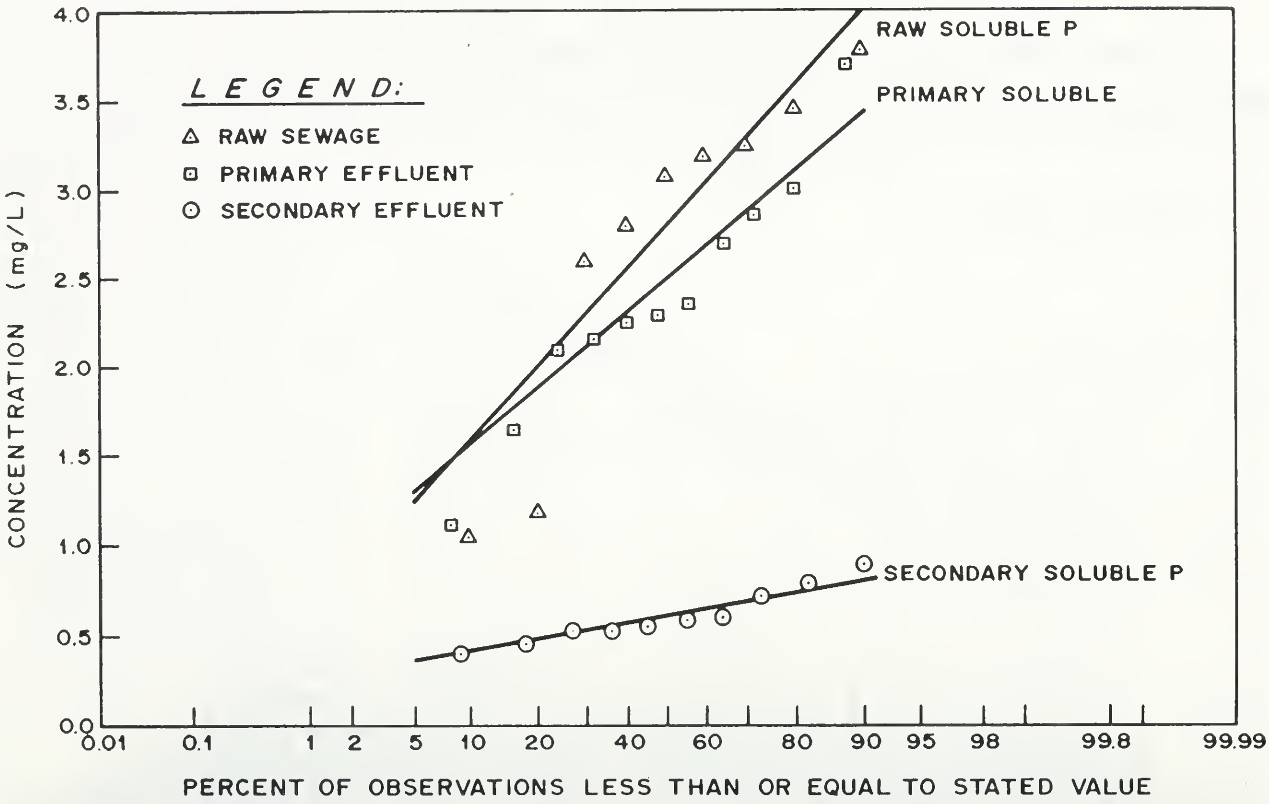


FIGURE 9-2 (b): WEST PLANT-SOLUBLE PHOSPHORUS

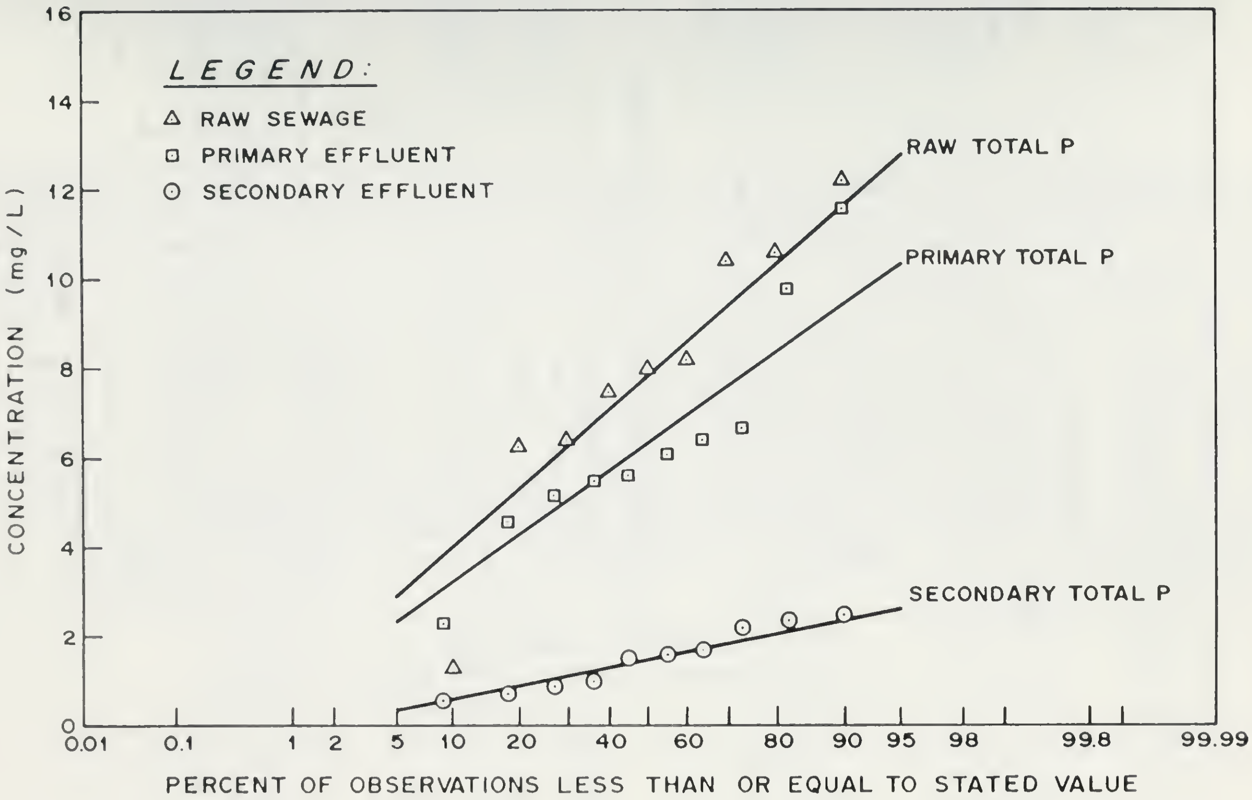


FIGURE 9-2 (c): EAST PLANT – TOTAL PHOSPHORUS

TABLE 9.6. SUMMARY OF KEY OPERATING PARAMETERS AFFECTING PHOSPHORUS REMOVAL AT DUFFIN CREEK WPCP

DATE	FLOW (m^3/d)		SECONDARY CLARIFIER LOAD ($m^3/m^2 \cdot d$)		WEST								EAST							
					Al DOSE (mg/L)	PRIMARY SOL. P (mg/L)	Al:P		EFFLUENT QUALITY (mg/L)				Al DOSE (mg/L)	PRIMARY SOL. P (mg/L)	Al:P		EFFLUENT QUALITY (mg/L)			
	AVG.	PEAK	AVG.	PEAK			WEIGHT	MOLAR	TSS	TOT. P	SOL. P	PART. P			WEIGHT	MOLAR	TSS	TOT. P	SOL. P	PART. P
Aug 5	157,420	199,200	14.8	18.8	3.2	3.00	1.1	1.3	8	0.64	0.41	0.23	3.2	3.15	1.0	1.1	15	1.60	0.83	0.77
6	155,400	192,00	14.6	18.1	3.2	2.86	1.1	1.3	9	0.69	0.60	0.09	3.2	2.85	1.1	1.3	14	1.62	0.96	0.66
7	182,020	228,000	17.2	21.5	2.7	1.63	1.7	2.0	6	0.73	0.45	0.28	2.7	3.70	0.7	0.8	11	1.55	1.06	0.49
11	161,550	216,000	15.2	20.4	3.1	2.69	1.2	1.4	6	0.97	0.72	0.25	3.1	2.84	1.1	1.3	14	2.20	1.45	0.75
12	158,490	196,800	14.9	18.5	3.2	2.15	1.5	1.7	7	1.96	0.79	1.17	3.2	3.00	1.1	1.3	21	2.50	1.42	1.08
13	155,300	199,200	14.6	18.8	3.2	3.70	0.9	1.0	10	1.00	0.54	0.46	3.2	3.12	1.0	1.1	12	2.35	0.79	1.56
18	180,330	244,800	17.0	23.1	2.8	2.35	1.2	1.4	9	0.88	0.53	0.35	2.8	2.11	2.3	1.5	5	0.74	0.72	0.02
25	162,410	216,000	15.3	20.4	3.1	2.35	1.3	1.5	7	-	0.58	-	3.1	2.35	1.3	1.5	9	-	0.85	-
27	291,870	468,000	27.5	44.1	1.7	1.08	1.6	1.8	19	1.07	0.45	0.62	1.7	1.20	1.4	1.6	26	0.91	0.48	0.43
28	223,940	276,000	21.1	26.0	2.1	2.28	0.9	1.0	25	1.46	0.45	1.01	2.1	2.71	0.8	0.9	22	0.99	0.53	0.46
Sept 2	215,900	216,000	20.3	20.4	2.3	2.10	1.1	1.3	4	1.15	0.88	0.27	2.3	2.70	0.9	1.0	4	0.53	0.48	0.05
3	167,640	204,000	15.8	19.2	3.0	2.25	1.3	1.5	18	0.75	0.52	0.23	3.0	2.05	1.5	1.7	8	-	0.88	-
AVG.	**184,356**	**238,000**	**17.4**	**22.4**	**2.8**	**2.37**	**1.2**	**1.4**	**10.7**	**1.03**	**0.58**	**0.45**	**2.8**	**2.65**	**1.0**	**1.1**	**13.4**	**1.50**	**0.87**	**0.63**

the west and east side, the concentrations of BOD_5, TSS, Total P and Soluble P influent to the east side were higher than those in the influent to the west side; the higher concentrations resulted in relatively higher loadings to the east side of the plant.

The average alum dose applied appears to be low at 2.8 mg Al/L. However, a molar ratio of Al:P for the west side of the plant of 1.4:1 was adequate to achieve 75% reduction, based on literature values. As shown by the average soluble phosphorus concentrations in the primary and secondary effluents from the west plant, approximately 75% of the soluble P was removed (seed Table 9.5).

The molar ratio of AL:P for the east side of the plant was relatively low at 1.1:1, which was lower than the ratio required for 75% reduction (molar ratio 1.38:1). The average percent reduction in soluble P between the east primaries and secondaries was 67%, based on concentrations of 2.65 mg/L and 0.87 mg/L, respectively.

9.5 Conclusions of Duffin Creek Monitoring Program

The monitoring program conducted at the Duffin Creek WPCP confirmed historical plant performance. Flows to the plant averaged 184,356 m^3/d during the monitoring period, representing an increase of about 25% over the average daily flow for 1985; the average flow observed during the sampling program was 98 percent of the average design capacity for the plant.

Observed influent quality was comparable to historical quality, with the exception of BOD_5, which was lower.

Sampling the west and east sides of the plant separately showed that, on average, pollutant concentrations in the influent to the east side were higher relative to the west side. Since equal alum dosages are applied to each side of the plant, the proportion of aluminum relative to phosphorus in the east plant is too low to support adequate phosphorus reduction.

10.0 PORT HOPE WATER POLLUTION CONTROL PLANT

10.1 Plant Description

The Port Hope WPCP provides wastewater treatment by conventional and high rate activated sludge processes for the Town of Port Hope. The original conventional activated sludge plant was constructed in 1956 and was designed to handle an average daily flow of 4,540 m^3/d (1.0 MIGD). The newer plant which was constructed in 1972 is a completely mixed, high rate activated sludge plant. The high rate plant is a Degremont Oxyrapid facility and was designed to process 4,540 m^3/d (1.0 MIGD). Figure 10.1 presents a process flow schematic of the Port Hope treatment facility. Key design information for the plant is presented in Table 10.1.

Raw sewage enters the treatment facility through an inlet-overflow chamber located at the northwest end of the plant. Wastewater is transferred via gravity through a Parshall flume (300 mm or 12 inch, throat) via a 600 mm (24 inch) diameter sewer. The peak capacity of the sewer is 25,900 m^3/d (5.7 MIGD). Flow can by-pass the plant via a high-level bypass weir situated in the inlet-overflow chamber; the capacity of the bypass sewer is 19,295 m^3/d (4.3 MIGD).

The influent raw sewage then passes into an aerated grit chamber, measuring 3.7m x 3.3m x 3.0m. Effluent from the grit chamber flows through a comminutor, which is used to break up coarse material. After preliminary treatment, the flow is split between the conventional activated sludge plant and the high-rate plant.

Conventional Activated Sludge (CAS) Plant

Treatment through the CAS plant consists of primary clarification, aeration and secondary settling.

Two primary clarifiers, each measuring 13.0m x 4.9m x 4.0m, provide a total surface area of 127.4 m^2 for primary sedimentation. Settled primary sludge is transferred to the inlet end of the tank by chain and flight mechanisms. The sludge is pumped to the anaerobic digester by two 2.2 kW (3 HP) sludge pumps. Surface scum is collected in troughs and removed manually for burial on-site.

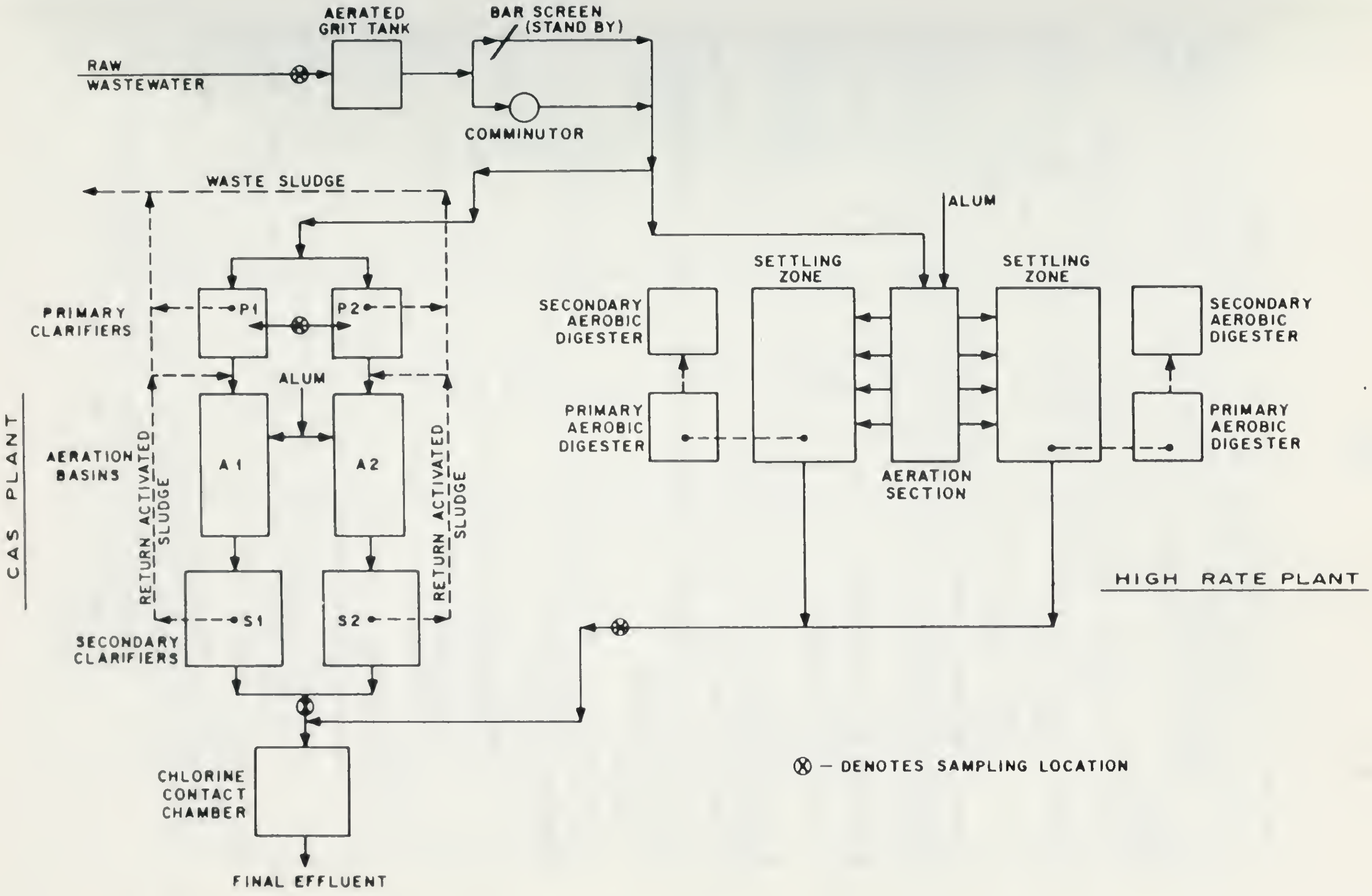


FIGURE 10-1: PROCESS FLOW SCHEMATIC OF PORT HOPE WPCP

TABLE 10.1. DESIGN SUMMARY - PORT HOPE WPCP

DESIGN CRITERIA	DESIGN VALUE	OPERATING LEVEL(1)
General		
Flow (m^3/d) Average Daily	9,080	8,010
Peak	20,430	23,735(2)
BOD$_5$ Concentration (mg/L)	225(3)	93
Loading (kg/d)	-	745
TSS Concentration (mg/L)	-	78
Loading (kg/d)	-	625
Sewage Collection System	100% Separate	
Primary Clarification		
HRT (hours)	2.0	2.3
Average Surface Loading (m^3/m^2·d)	36.0	31.7
Peak Surface Loading (m^3/m^2·d)	72.0	83.6
Aeration System		
CAS: HRT (hours)	8.0	9.1
High Rate: HRT (hours)	3.3	3.7
Phosphorus Removal		
Chemical	Alum	-
Average Dosage (mg Al/L) 1985	-	3.0
Secondary Clarifiers		
CAS: HRT (hours)	3.0	3.4
Average Surface Loading (m^3/m^2·d)	29.4	25.9
Peak Surface Loading (m^3/m^2·d)	58.8	68.3
High Rate:		
HRT (hours)	3.2	3.6
Average Surface Loading (m^3/m^2·d)	17.1	19.4
Peak Surface Loading (m^3/m^2·d)	38.5	44.7
Chlorination		
HRT (min) @ Average Flow	30	34

Notes:
(1) Based on 1981-1985 historical data.
(2) Based on average peak flow for November 1985.
(3) Taken from design report for CAS plant.
(4) Applies to CAS plant only.

Two aeration basins are used to biologically treat the wastewater. Each basin measures 38.0m x 5.5m x 4.0m and consists of four cells which are operated in series. Effluent from the primary clarifiers is aerated for 8.0 hours (at average daily design flow) by submerged diffusers. Air is supplied to the tanks by two 150 kW (200 HP) blowers.

Alum is metered into the aeration basins. The alum is stored in a 27.2 m^2 (6,000 gal) storage tank and is applied to the wastewater by a single chemical feed pump.

Secondary clarification of the mixed liquor from the aeration basins is accomplished in two final settling tanks, each 15.9m x 4.9m x 3.7m. The surface area and volume of the secondary clarifiers are 156 m^2 and 577 m^3, respectively. Settled sludge is collected by a chain and flight mechanism and is pumped back to either the aeration basins for primary tanks. Overflow from the secondary clarifiers is transferred to the chlorine contact chamber via a 500 mm (20 inch) diameter pipe.

Sludge treatment prior to disposal involves single stage anaerobic digestion. The digester capacity is approximately 1,120 m^3. Digested sludge is removed monthly by two plunger-type sludge pumps and trucked off-site for disposal.

High Rate Plant

The high rate plant consists of aeration, settling and aerobic digestion of waste activated sludge.

Raw sewage enters the aeration section after preliminary treatment. The wastewater is aerated by a 150 kW (200 HP) blower for approximately 3.3 hours (at average design flow). The total volume of the aeration section is 320 m^3 and measures 32.3m x 2.4m x 4.1m. Activated sludge produced in the aeration section is allowed to settle out in the settling zones adjacent to the aeration section (see Figure 10.1). From there, it is recycled back to the aeration section via recirculating chimneys. Submerged diffusers are used to aerate the mixed liquor. The total capacity of the two settling zones is 600 m^3, with each zone measuring 32.3m x 2.3m x 4.1m.

Alum is applied to the influent wastewater in the aeration section by a single chemical feed pump, which is set manually.

Effluent from the settling zones is transferred to the chlorine contact chamber via a 450 mm diameter pipe. Sludge from the bottoms of the aeration section and settling zones is air lifted to one of two primary aerobic digesters, located on either side of the high rate plant. Total sludge detention time in both the primary and secondary digesters is 30 days. Supernatant from the secondary digesters is recycled back to the aeration section of the plant. Sludge is transported to the sludge drying lagoon prior to final disposal at a landfill site.

Effluents from the conventional activated sludge and high rate plants is disinfected with chlorine gas in a 10.2m x 7.9m x 2.4m contact chamber. Chlorine dosage is automatic and in proportion to influent flow.

10.2 Historical Performance

Table 10.2 provides a summary of the annual performance of the Port Hope WPCP for 1981 through 1985.

As shown in Table 10.2, the Port Hope treatment facility typically discharges a high quality effluent. The five-year average effluent concentrations for BOD_5, TSS and total phosphorus were 5.5 mg/L, 5.8 mg/L and 0.64 mg/L, respectively, which are well below Ministry of the Environment effluent guidelines. The influent concentrations indicate that the plant typically receives a low strength wastewater. The average daily flow to the plant based on averages for the past five years, was 8,010 m^3/d, equivalent to almost 90% of the average daily design capacity. Monthly effluent quality data for 1984 and 1985 (BOD_5, TSS, total P) are presented in Table 10.3. Effluent BOD_5 levels have been consistently below MOE guidelines. Effluent concentrations of TSS and total P were also low. The total suspended solids content of the final effluent never exceeded 10.0 mg/L. The highest monthly average total phosphorus level was 0.79 mg/L (February 1985).

10.3 Sampling Program

The Port Hope WPCP was sampled on twelve days between September 30 and October 22, 1986. Twenty-four hour composite samples of raw sewage (upstream of the aerated grit chamber) and primary effluent from the conventional activated sludge plant were collected. Twenty-four hour flow proportional samples of effluent from the secondary clarifiers (CAS plant) and settling zone (high rate plant) were also collected. The sampling locations

TABLE 10.2. ANNUAL AVERAGE PERFORMANCE OF PORT HOPE WPCP

PARAMETER	YEAR					5 YEAR AVERAGE (81-85)
	1981	1982	1983	1984	1985	
Average Daily Flow (10^3 m^3/d)	8.16	6.64	7.42	8.38	9.59	8.01
BOD_5 - Influent (mg/L)	77.0	64.3	121.7	92.4	110.5	92.9
BOD_5 - Effluent (mg/L)	4.1	4.0	8.0	5.4	6.0	5.5
TSS - Influent (mg/L)	102.0	89.3	71.1	69.0	57.1	78.2
TSS - Effluent (mg/L)	7.0	6.3	4.5	5.7	5.4	5.8
Total P - Influent (mg/L)	4.10	4.20	4.22	3.06	1.93	3.54
Total P - Effluent (mg/L)	0.55	1.00	0.57	0.53	0.56	0.64

TABLE 10.3. MONTHLY AVERAGE PERFORMANCE OF PORT HOPE WPCP

YEAR	MONTH	EFFLUENT CONCENTRATIONS					
		BOD_5		TSS		TOTAL P	
		(mg/L)	(n)	(mg/L)	(n)	(mg/L)	(n)
1984	Jan.	12.0	5	2.1	1	0.26	1
	Feb.	9.1	4	4.3	1	0.28	1
	Mar.	8.1	6	6.3	1	0.36	1
	Apr.	6.9	5	6.3	1	0.32	1
	May	5.0	5	5.0	4	0.71	4
	Jun.	1.5	4	3.8	4	0.71	4
	Jul.	1.9	4	10.0	4	0.67	4
	Aug.	5.5	4	4.0	4	0.74	4
	Sep.	1.1	2	5.1	2	0.50	2
	Oct.	1.9	6	5.9	6	0.64	6
	Nov.	7.5	4	7.0	4	0.41	4
	Dec.	4.5	3	8.3	3	0.76	3
1985	Jan.	5.4	4	5.6	4	0.76	4
	Feb.	4.7	4	6.7	4	0.79	4
	Mar.	8.0	6	5.3	6	0.48	6
	Apr.	5.9	5	5.5	5	0.60	5
	May	3.1	6	4.4	6	0.68	6
	Jun.	3.5	5	5.5	5	0.44	5
	Jul.	3.5	5	4.1	5	0.36	5
	Aug.	3.1	6	4.4	6	0.37	6
	Sep.	1.7	5	4.3	5	0.56	5
	Oct.	-	-	-	-	-	-
	Nov.	10.6	4	6.1	5	0.62	5
	Dec.	16.1	3	7.7	3	0.51	3

n = Number of samples

for these twenty-four hour samples were shown in Figure 10.1. In addition, samples of mixed liquor and return/waste activated sludge were also collected.

10.4 Results of Sampling Program

Table 10.4 presents a compilation of plant operating data, supplemented by CANVIRO data, for the monitoring period.

The average daily flow during the monitoring period was 9,635 m^3/d, which is slightly above the average daily design capacity for the plant. The average flow observed during the monitoring period was higher than the five-year average, but was consistent with the trend shown by the annual average flowrates from 1982 through 1985. The maximum flow observed during the monitoring period was just over 21,600 m^3/d, which is also higher than the peak design capacity.

During the sampling period, all available tankage was used for sludge storage. As a result, activated sludge recycling and wasting were minimal; no SRTs were calculated for either biological system. However, SVIs, obtained from plant operating records, indicated that sludge settling properties were acceptable (SVI <120).

Alum addition varied from day-to-day, with the average volume applied being 640 L, equivalent to a dosage of 2.4 mg Al/L, based on an aluminum concentration of 31.8 g/L in the alum. The quantity of alum applied ranged from 556 L up to 926 L, which resulted in dosages between 0.8 and 3.2 mg/L as Al, respectively.

The results of the monitoring program are presented in Table 10.5.

Raw sewage strength during the monitoring period was much lower than previously observed (see Table 10.2), with the exception of total phosphorus. The average BOD_5 and TSS concentrations recorded during the monitoring period were 25.5 mg/L and 47.0 mg/L, respectively. The previous five-year annual average BOD_5 concentration was 92.9 mg/L and the 5-year annual average TSS concentration was 78.2 mg/L. The average BOD_5 and TSS levels observed during the monitoring period represent decreases of 73 percent and 40 percent, respectively, compared to the five-year averages shown in Table 10.2. The total phosphorus concentration in the raw sewage averaged 2.94 mg/L of which the soluble fraction accounted for 67 percent. The five-year

TABLE 10.4. SUMMARY OF PORT HOPE WPCP OPERATING CONDITIONS
(SEPTEMBER 30 - OCTOBER 22, 1986)

DATE	AVERAGE FLOW (m^3/d)	PEAK FLOW (m^3/d)	CAS PLANT				HIGH RATE PLANT				ALUM USED (L)	ALUM DOSAGE* (mg/L)
			MLSS (mg/L)	MLVSS (%)	R.A.S. (mg/L)	SVI	MLSS (mg/L)	MLVSS (%)	R.A.S. (mg/L)	SVI		
Sept 30	21,653	22,700	2,040	50.0		50.5	5,700	57.2		56.5	556	0.8
Oct. 1	15,130	22,700	2,160	55.6	15,880	50.0	6,140	57.7	9,040	75.0	741	1.6
2	11,536	18,160	2,220	48.6	17,900	51.5	5,960	58.7	8,620	86.5	741	2.0
6	10,819	18,160	1,900	53.7	11,700	49.0	5,280	58.0	7,440	104.0	926	2.7
7	9,113	15,890	1,740	52.7	9,920	52.5	5,220	59.0	8,600	103.0	646	2.3
8	7,974	13,620	2,780	54.0	20,800	54.0	5,780	60.2	7,800	103.0	646	2.6
9	7,720	13,620	2,700	51.1	10,180	54.0	5,280	61.0	6,360	63.0	556	2.3
15	6,782	10,442	2,460	51.2	10,480	55.0	4,120	60.7	6,380	52.5	556	2.6
16	6,362	9,988	2,240	53.6	7,760	50.5	3,880	60.3	5,620	52.5	556	2.8
20	6,344	9,534	2,360	49.1	7,800	52.5	4,450	56.6	7,000	65.0	646	3.2
21	5,954	9,534	2,360	48.3	7,820	54.5	5,070	60.2	6,000	55.0	556	3.0
22	6,233	10,442	2,980	55.7	14,860	53.0	5,080	64.2	6,520	58.0	556	2.8
Average	9,635	14,566	2,328	52.0	12,282	52.3	5,163	59.5	7,216	72.8	640	2.4
Maximum	21,653	22,700	2,980	55.7	20,800	55.0	6,140	64.2	9,040	104.0	926	3.2
Minimum	5,954	9,534	1,740	48.3	7,760	49.0	3,880	56.6	5,620	52.5	556	0.8

TABLE 10.5. SUMMARY OF PERFORMANCE MONITORING DATA FOR PORT HOPE WPCP

DATE	STREAM	CONCENTRATION (mg/L)			
		BOD_5	TSS	TOTAL P	SOLUBLE P
30/09	Raw	40.0	90.0	2.76	1.40
	Primary Eff.	-	-	4.40	2.35
	Secondary Eff. - Old	3.0	30.0	1.22	<0.28
	- New	3.0	30.0	0.62	0.30
01/10	Raw	2.5	12.0	1.33	1.13
	Primary Eff.	-	-	7.33	1.05
	Secondary Eff. - Old	1.1	2.0	<0.21	<0.21
	- New	1.0	4.0	0.39	0.39
02/10	Raw	3.0	10.0	1.96	1.51
	Primary Eff.	-	-	2.40	1.20
	Secondary Eff. - Old	1.0	2.0	<0.20	<0.20
	- New	1.8	10.0	0.80	0.35
06/10	Raw	13.0	40.0	2.26	1.59
	Primary Eff.	-	-	1.70	1.28
	Secondary Eff. - Old	1.4	3.0	<0.26	<0.20
	- New	2.0	4.0	0.61	0.47
07/10	Raw	23.0	24.0	2.78	1.87
	Primary Eff.	-	-	4.40	1.75
	Secondary Eff. - Old	1.5	1.0	<0.20	<0.25
	- New	2.2	2.0	0.60	0.48
08/10	Raw	19.0	30.0	3.30	2.44
	Primary Eff.	-	-	2.00	1.83
	Secondary Eff. - Old	1.0	3.0	<0.45	<0.23
	- New	1.3	3.0	0.70	0.38
09/10	Raw	26.0	60.0	2.77	2.00
	Primary Eff.	-	-	2.90	1.97
	Secondary Eff. - Old	1.0	2.0	<0.45	<0.23
	- New	21.2	12.0	1.00	0.50
15/10	Raw	21.0	70.0	3.00	2.40
	Primary Eff.	-	-	1.95	1.60
	Secondary Eff. - Old	1.2	2.0	<0.30	<0.57
	- New	-	-	2.20	-
16/10	Raw	15.0	52.0	3.10	1.85
	Primary Eff.	-	-	4.00	1.40
	Secondary Eff. - Old	1.0	1.0	0.64	<0.45
	- New	-	-	1.29	-
20/10	Raw	50.0	67.0	4.50	2.70
	Primary Eff.	-	-	2.43	1.93
	Secondary Eff. - Old	3.0	6.0	0.55	<0.28
	- New	5.0	4.0	2.72	0.80
21/10	Raw	42.0	45.0	3.90	2.53
	Primary Eff.	-	-	2.93	2.20
	Secondary Eff. - Old	4.0	6.0	<0.30	<0.33
	- New	3.0	2.0	0.99	0.56
22/10	Raw	26.0	64.0	3.56	2.87
	Primary Eff.	-	-	2.88	2.20
	Secondary Eff. - Old	1.1	3.0	<0.30	<0.30
	- New	2.0	4.0	1.13	1.08
Averages	Raw	25.5	47.0	2.94	1.96
	Primary Eff.	-	-	3.28	1.64
	Secondary Eff. - Old	1.7	5.1	<0.42	<0.29
	- New	4.3	7.5	1.31	0.53

annual average total phosphorus level was 3.54 mg/L. High rainfall during the monitoring period undoubtedly contributed to the lower wastewater strength measured.

Effluent quality observed during the monitoring period confirmed the historical pattern of superior plant performance. Average effluent BOD_5 from the conventional activated sludge plant was 1.7 mg/L and from the high rate plant was 4.3 mg/L, for an overall average of 3.0 mg/L. Total suspended solids concentrations in the effluents from the CAS and high rate plants were 5.1 mg/L and 7.5 mg/L, respectively. The combined overall average TSS level in effluent from the plant, prior to chlorination was 6.3 mg/L. Total phosphorus concentrations were <0.42 mg/L and 1.31 mg/L for the CAS and high rate plants, respectively; the overall average was <0.87 mg/L. Soluble phosphorus average <0.29 mg/L for the CAS plant and 0.53 mg/L for the high rate plant. Probability distributions for total and soluble phosphorus are shown in Figure 10.2 and 10.3.

Key operating parameters affecting phosphorus removal at the Port Hope WPCP are presented in Table 10.6. Secondary clarifier loadings to both the conventional and high rate plant were relatively low, averaging 31.2 $m^3/m^2\cdot d$ for the former and 18.1 $m^3/m^2\cdot d$ for the latter. The low hydraulic loading coupled with good sludge settleability produced low effluent TSS concentrations.

Soluble phosphorus in the primary effluent from the CAS plant was, on average, 1.73 mg/L. The high rate plant, which does not have primary clarification, received an average soluble phosphorus concentration of 2.02 mg/L (from raw sewage). Since alum dosages to each plant were approximately equal, the ratio of aluminum to soluble phosphorus (Al:P) was higher, on average, for the conventional plant (at >1.6 molar ratio), than for the high rate plant (at 1.3 molar ratio). As a result of this, the soluble phosphorus in the effluent from the high rate plant was typically higher (average 0.53 mg/L) than for the CAS plant (average <0.29 mg/L). The effluent total phosphorus was also higher for the high rate plant (average 1.31 mg/L) than for the CAS plant (average <0.42 mg/L). Since particulate phosphorus was generally low for both plants due to good suspended solids removal, the discrepancies in total phosphorus removal between the plants can be attributed to the different aluminum to phosphorus ratios.

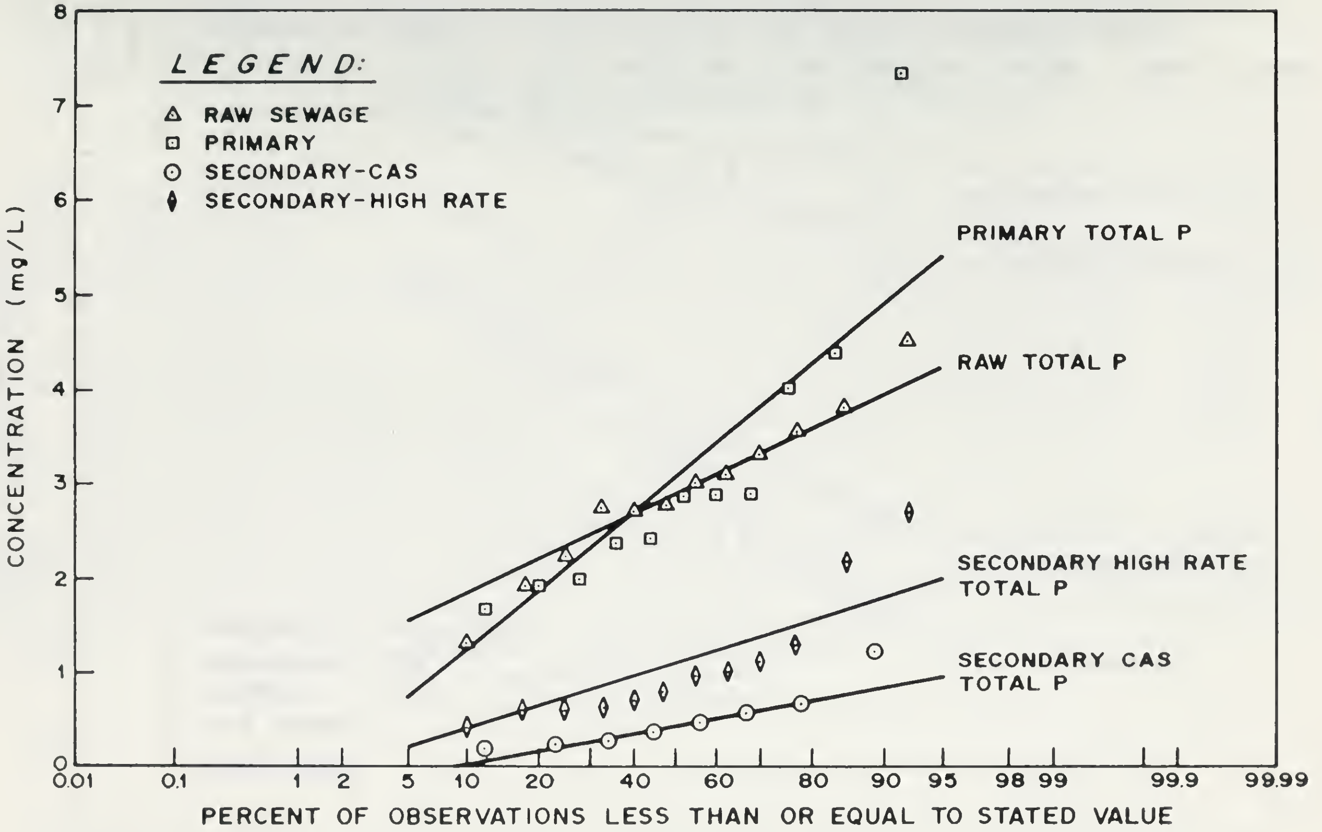


FIGURE 10-2 —PROBABILITY DISTRIBUTIONS FOR PHOSPHORUS AT PORT HOPE WPCP (a) TOTAL PHOSPHORUS

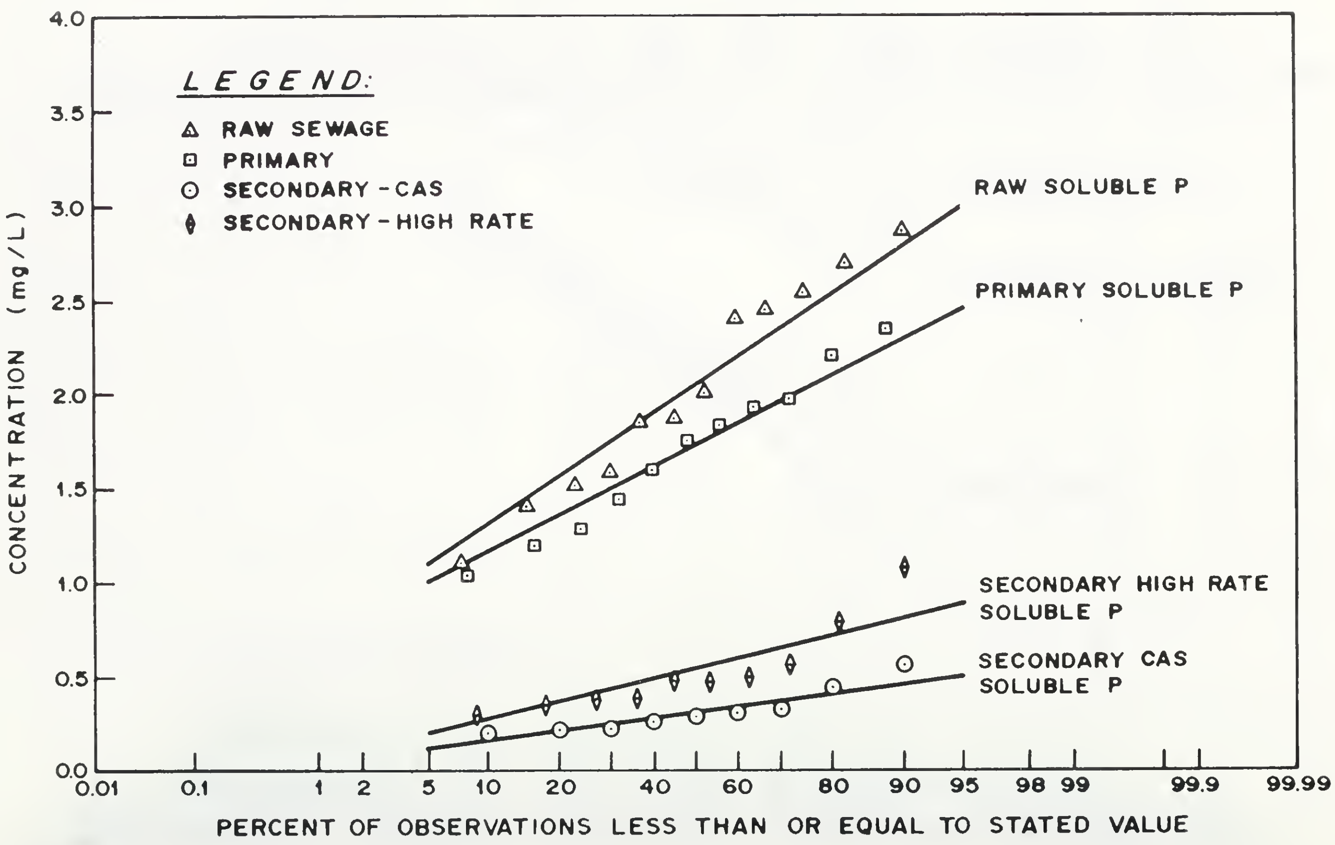


FIGURE 10-3 — SOLUBLE PHOSPHORUS

TABLE 10.6. SUMMARY OF OPERATING PARAMETERS AFFECTING PHOSPHORUS REMOVAL AT THE PORT HOPE WPCP

DATE	FLOWS (10^3 m^3/d)		CAS PLANT (old)										HIGH RATE PLANT (new)										COMBINED EFFLUENT QUALITY (mg/L)			
			CLARIFIER SURFACE LOAD (m^3/m^2/d)		ALUM DOSAGE	AL:P RATIO**		EFFLUENT QUALITY (mg/L)				CLARIFIER SURFACE LOAD (m^3/m^2/d)		ALUM DOSAGE	AL:P RATIO***		EFFLUENT QUALITY (mg/L)							
	AVERAGE	PEAK	AVERAGE	PEAK	(mg/L)	WEIGHT	MOLAR	TSS	TP	SOL.P	PART.P	AVERAGE	PEAK	(mg/L)	WEIGHT	MOLAR	TSS	TP	SOL.P	PART.P	TSS	TP	SOL.P	PART.P
Sep. 30	21.65	22.7	70.1	73.5	0.8	<0.3	>0.4	30	1.22	<0.28	>0.94	40.8	42.8	0.8	0.6	0.6	30	0.62	0.30	0.32	30	0.92	<0.29	>0.63
Oct. 1	15.13	22.7	43.0	73.5	1.6	>1.5	>1.6	2	<0.21	<0.21	*	28.5	42.8	1.6	1.4	1.5	4	0.39	0.39	0.00	3	<0.30	<0.30	*
2	11.54	18.16	37.4	58.8	2.0	>1.7	>1.9	2	<0.20	<0.20	*	21.7	34.2	2.0	1.4	1.5	10	0.80	0.35	0.45	6	<0.50	<0.28	*
6	10.82	18.16	36.0	58.8	2.7	>2.1	>2.3	3	<0.26	<0.20	*	20.4	34.2	2.7	1.7	1.9	4	0.61	0.47	0.14	4	<0.29	<0.34	*
7	9.11	15.89	29.3	51.5	2.3	>1.3	>1.4	1	<0.20	<0.25	*	17.2	29.9	2.3	1.2	1.3	2	0.60	0.48	0.12	2	<0.40	<0.37	*
8	7.97	13.62	25.8	44.1	2.6	>1.4	>1.5	3	<0.45	<0.23	*	15.0	25.7	2.6	1.1	1.2	3	0.70	0.38	0.32	3	<0.58	<0.31	*
9	7.72	13.62	25.0	44.1	2.3	>1.2	>1.3	2	<0.45	<0.23	*	14.5	25.7	2.3	1.1	1.3	12	1.00	0.50	0.50	7	<0.73	<0.37	*
15	6.78	10.44	22.0	33.8	2.6	>1.6	>1.8	2	<0.30	<0.57	*	12.8	19.7	2.6	1.1	1.2	-	2.20	-	*	-	*	-	*
16	6.36	9.99	20.6	32.3	2.8	>2.0	2.2	1	0.64	<0.45	>0.19	12.0	18.8	2.8	1.5	1.7	-	1.29	-	*	-	-	-	*
20	6.34	9.53	20.5	30.9	3.2	>1.7	1.8	6	0.55	<0.28	>0.27	11.9	18.0	3.2	1.2	1.3	4	2.72	0.80	1.92	5	1.64	<0.54	1.1
21	5.95	9.53	19.3	30.9	3.0	>1.3	>1.5	6	<0.30	<0.33	*	11.2	18.0	3.0	1.2	1.3	2	0.99	0.56	0.43	4	<0.65	<0.45	*
22	6.23	10.44	20.2	33.8	2.8	>1.3	>1.4	3	<0.30	<0.30	*	11.7	19.7	2.8	1.0	1.1	4	1.13	1.08	0.05	4	<0.72	<0.69	*
Average	9.64	14.57	31.2	47.2	2.4	>1.5	>1.6	5.1	<0.42	<0.29	*	18.1	27.5	2.4	1.2	1.3	7.5	1.31	0.53	0.38	6.8	<0.87	<0.39	*

* Insufficient data to calculate particulate phosphorus.

** Based on primary effluent soluble phosphorus.

*** Based on raw wastewater soluble phosphorus.

10.5 Conclusions of Port Hope WPCP Monitoring Program

The monitoring program conducted at the Port Hope WPCP confirmed historical plant performance. Flows to the plant average 9,635 m^3/d during the monitoring period, representing less than a 0.5 percent increase over the average flow for 1985 and almost 6 percent above the average design capacity for the plant. Influent strength was much lower than historically observed, with the exception of total phosphorus, which was only slightly lower.

Separate sampling of effluent from the conventional activated sludge plant and the high rate plant showed the conventional plant was, on average, producing a better quality effluent than the high rate plant.

Total phosphorus concentrations in secondary effluent discharged from the CAS and high rate plants were <0.42 mg/L and 1.31 mg/L, respectively. Corresponding soluble phosphorus concentrations were <0.29 mg/L and 0.53 mg/L. Overall average total and soluble phosphorus levels in combined effluent were <0.87 mg/L and <0.41 mg/L. Low effluent soluble phosphorus levels reflect the high average aluminum dosage of 2.40 mg/L. The average Al:Sol.P (primary effluent) for the CAS plant was >1.6:1 (molar) which would ensure high phosphorus reduction. However, for the high rate plant, the Al:Sol.P (raw sewage) was 1.3:1, which is the suggested lower limit for removal of 75% of influent phosphorus.

11.0 TRENTON WATER POLLUTION CONTROL PLANT

11.1 Plant Description

The Trenton WPCP is a conventional activated sludge plant, located on the Bay of Quinte and operated by the Ontario Ministry of the Environment. The plant, which currently serves a population of over 15,300, has an average daily flow capacity of 15,911 m^3/d (3.5 MIGD) and a peak hydraulic capacity of 71,600 m^3/d (15.8 MIGD), which is equivalent to 4.5 times the average design flow. Figure 11.1 presents a process flow schematic of the Trenton WPCP. Although not shown in the schematic diagram, the Trenton WPCP is actually a two-tier plant in which the primary clarifiers and aeration basins are on an upper level and the secondary clarifiers and chlorination contact channel are at ground level. Key design information for the plant is provided in Table 11.1.

Raw sewage enters the treatment facility through a 0.60 m (24 inch) diameter forcemain which pipes the wastewater directly into a 15.5 m x 4.8 m x 3.4 m aerated grit tank. Two 54.3 L/s positive displacement blowers force air into the sewage, which is held in the tank for 23 minutes at average flow. From the aerated grit tank, the sewage passes through two 0.91 m barminutors, used to break up coarse material.

After preliminary treatment, the wastewater flows into either of two primary clarifiers, each measuring 15.5 m x 9.8 m x 3.7 m. A total surface area of 304 m^2 is provided for primary sedimentation. The total primary clarifier volume is 1124 m^3. Settled raw sludge is collected by chain flight longitudinal and cross collectors. Three plunger-type raw sludge transfer pumps, each rated at 7.57 L/s at 24.4 m TDH, transfer the primary sludge to the primary digester. Collector flights at the surface of each tank are used to remove scum, which is also pumped to the primary digester by two torque flow scum pumps, each rated at 3.8 L/s at 18.3 m TDH.

Biological treatment at the Trenton WPCP involves aeration of the effluent from the primary clarifiers for 4.2 hours (at average design flow). Two rectangular basins, each 40.2 m x 8.0 m x 4.6 m, provide a total volume of 2959 m^3 for aeration. Oxygen transfer is facilitated by four 149.1 kW blowers.

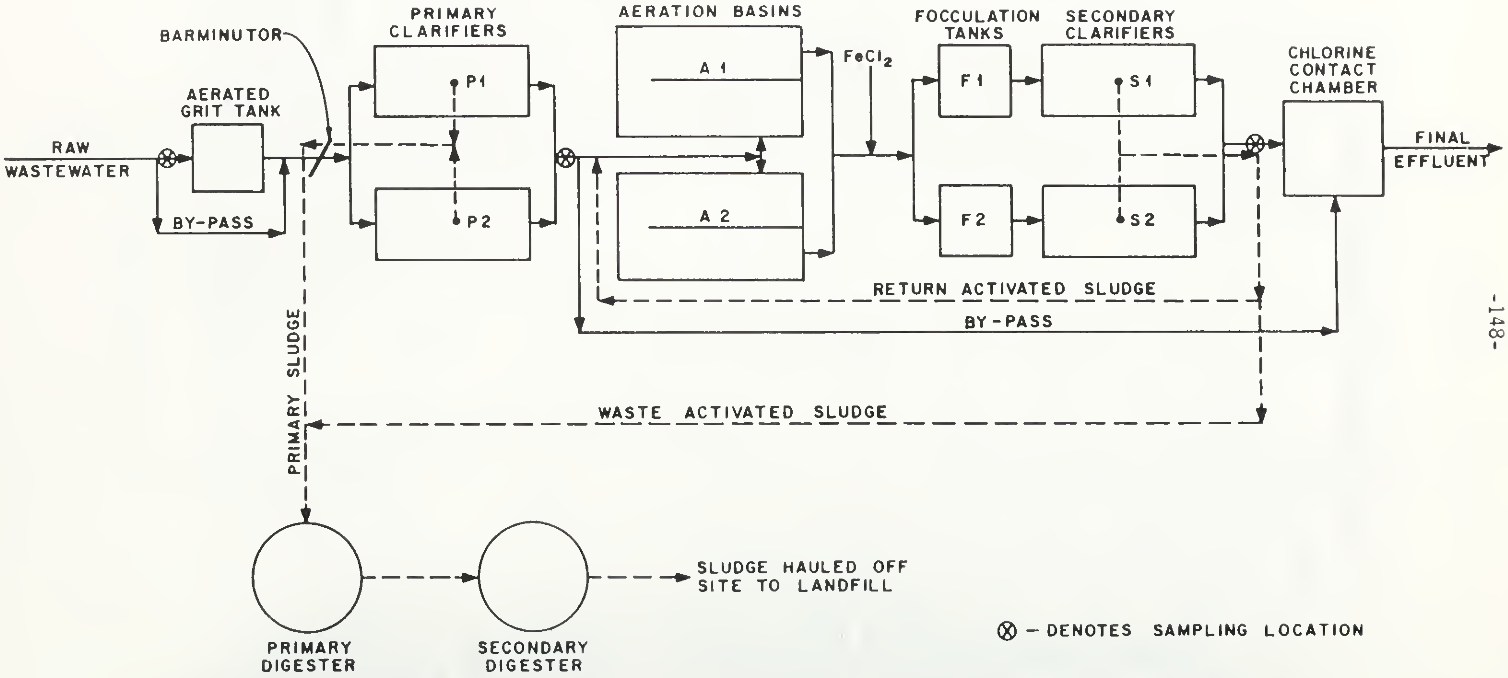


FIGURE 11-1: PROCESS FLOW SCHEMATIC OF TRENTON WPCP

TABLE 11.1. DESIGN SUMMARY - TRENTON WPCP

DESIGN CRITERIA		DESIGN VALUE	OPERATING LEVEL(1)
General			
Flow (m^3/d)	Average Daily	15,911	10,460
	Peak	71,600	40,330(2)
BOD_5	Concentration (mg/L)	250	180
	Loading (kg/d)	-	1,883
TSS	Concentration (mg/L)	300	166
	Loading (kg/d)	-	1,736
Sewage Collection System		100% Separate	-
Primary Clarification			
HRT (hrs)		1.7	2.6
Average Surface Loading (m^3/m^2.d)		34.2	22.5
Peak Surface Loading (m^3/m^2.d)		153.9	86.7
Aeration System			
HRT (hrs)		4.2	6.4
Return Sludge Rate (%)		30	-
Phosphorus Removal			
Chemical		Ferrous Chloride, $FeCl_2$	-
Average Dosage (mg Fe/L)	1984	-	15.0
	1985	-	10.4
Secondary Clarification			
HRT (hrs)		4.5	6.8
Average Surface Loading (m^3/m^2.d)		39.1	25.7
Peak Surface Loading (m^3/m^2.d)		175.9	134.7
Chlorination			
HRT (min) @ Average Flow		87	132

Notes: (1) Information based on 1981-1985 historical data, except as noted.
(2) Based on flow recorded in April 1984.

Ferrous chloride is metered to the effluent from the aeration basins. Flocculation basins upstream of the secondary clarifiers allow the ferrous chloride to mix with the mixed liquor.

Secondary clarification of the mixed liquor from the aeration basins is accomplished in two rectangular tanks, each 41.4 m x 9.8 m x 3.7 m. The surface area and volume provided by the secondary clarifiers are approximately 811 m^2 and 3002 m^3, respectively. Sludge is removed from the bottom of the secondary clarifiers by chain flight longitudinal and cross collectors. Two horizontal non-clog pumps, each rated at 184 L/s at 17.7 m TDH, are used to remove the activated sludge from the tanks.

Overflow from the secondary clarifiers is disinfected by gas chlorination for 87 minutes (at average design flow). A travelling bridge on the first pass of the contact chamber is used to remove bottom sludge and surface scum, which are pumped to the digesters by two torque flow pumps (each rated at 5.8 L/s at 24.4 m TDH).

Sludge treatment prior to disposal involves two-stage anaerobic digestion. Gas produced during sludge digestion is used not only to maintain a constant temperature in the digesters, but is also used as a fuel to heat the plant buildings. Digested sludge is disposed of in a sanitary landfill.

11.2 Historical Performance

Table 11.2 provides a summary of the annual performance of the Trenton WPCP for 1981 through 1985.

As shown in Table 11.2, the plant typically discharges a high quality effluent. The five-year average effluent concentrations for BOD_5, suspended solids and total phosphorous were 12.6 mg/L, 11.7 mg/L and 0.78 mg/L, respectively, which are all below the Ontario Ministry of the Environment guidelines of 25 mg/L, 25 mg/L and 1 mg/L, respectively. The average influent concentrations shown in Table 11.2 indicate that the plant typically receives a medium strength wastewater. The average daily flow to the plant, based on daily averages for the past five years was 10,460 (m^3/d), equivalent to 66% of the average design capacity.

TABLE 11.2. ANNUAL AVERAGE PERFORMANCE OF TRENTON WPCP

PARAMETER	YEAR					5 YEAR AVERAGE (81-85)
	1981	1982	1983	1984	1985	
Average Daily Flow (10^3 m^3/d)	10.92	9.59	9.84	10.83	11.17	10.46
BOD - Influent (mg/L)	126.7	162.6	176.7	201.3	234.8	180.5
BOD - Effluent (mg/L)	9.0	15.1	14.1	13.8	10.8	12.6
TSS - Influent (mg/L)	143.0	185.0	159.4	165.4	176.2	165.8
TSS - Effluent (mg/L)	7.9	13.0	12.9	11.6	13.0	11.7
Total P - Influent (mg/L)	5.48	5.68	5.84	5.93	6.07	5.80
Total P - Effluent (mg/L)	0.71	1.14	0.82	0.58	0.67	0.78

Monthly effluent quality data for 1984 and 1985 (BOD_5, total suspended solids and total phosphorus) are presented in Table 11.3. With the exception of December 1984, total phosphorus concentrations in the effluent from the plant have been consistently less than 1.0 mg/L. The plant also has a site specific effluent phosphorus requirement of 0.5 mg/L for May to October. This limit was exceeded for three of the six months in 1984 and five of the six months in 1985. Effluent suspended solids concentrations exceeded 15 mg/L for 6 of the 24 months, with the maximum level discharged in November 1985. BOD_5 in the effluent from the Trenton WPCP appears subject to variation with minimum and maximum monthly averages of 3.2 mg/L and 24.0 mg/L, respectively (observed for July 1985 and January 1984).

11.3 Sampling Program

The Trenton WPCP was sampled on twelve days between September 24 and October 16, 1986. Twenty-four hour composite samples of raw sewage (upstream of the aerated grit tank) and primary effluent were collected. Twenty-four hour flow proportional samples of effluent from the secondary clarifiers (prior to chlorination) were also collected. The sampling locations for these twenty-four hour samples were shown in Figure 11.1. In addition, grab samples of mixed liquor from the aeration tanks and return/waste activated sludge were collected in order to calculate solids retention times (SRTs).

11.4 Results of Sampling Program

Table 11.4 presents a compilation of plant operating data, supported by CANVIRO data for the month long sampling period at the Trenton WPCP.

The average daily flow during the monitoring period was 17,241 m^3/d, equivalent to approximately 110 percent of design capacity. The average daily flow observed during the monitoring period was 65 percent higher than the 5-year average. The maximum flow recorded during the monitoring period was 36,000 m^3/d, which was observed on four of the twelve sampling dates. All flows were less than the peak plant capacity of 71,600 m^3/d. Flows were bypassed, after primary treatment, to the chlorine contact chamber on four separate occasions. The largest volume bypassed was 4500 m^3 (October 1). It should be noted that flows up to 2.5 times the average daily design

TABLE 11.3. MONTHLY AVERAGE PERFORMANCE OF TRENTON WPCP

YEAR	MONTH	EFFLUENT CONCENTRATIONS					
		BOD_5		TSS		TOTAL P	
		mg/L	n	mg/L	n	mg/L	n
1984	Jan.	24.0	4	19.0	20	0.54	5
	Feb.	16.0	5	13.0	20	0.43	4
	Mar.	18.0	5	9.9	22	0.62	7
	Apr.	18.0	13	19.0	19	0.68	5
	May	19.0	4	8.0	22	0.46	9
	June	11.0	3	7.8	21	0.50	7
	July	5.6	5	5.8	21	0.55	7
	Aug.	8.0	5	6.0	22	0.61	7
	Sept.	5.5	4	6.0	16	0.54	7
	Oct.	11.5	4	13.9	21	0.37	7
	Nov.	13.0	4	16.0	20	0.42	7
	Dec.	16.0	4	15.0	19	1.20	2
1985	Jan.	9.0	3	15.0	22	0.91	7
	Feb.	8.6	3	16.0	19	0.71	7
	Mar.	12.0	5	15.0	21	0.55	6
	Apr.	7.5	4	12.0	20	0.54	8
	May	12.0	4	10.0	22	0.90	8
	June	7.6	4	7.2	20	0.83	9
	July	3.2	3	11.0	22	0.60	7
	Aug.	8.9	4	7.6	21	0.54	9
	Sept.	5.3	5	9.7	20	0.77	7
	Oct.	17.0	5	10.0	21	0.38	6
	Nov.	16.0	4	26.0	20	0.70	4
	Dec.	23.0	3	16.9	19	0.60	4

n - number of samples

TABLE 11.4. SUMMARY OF TRENTON WPCP OPERATING CONDITIONS (SEPTEMBER 24 - OCTOBER 16, 1986)

DATE	AVERAGE FLOW (m^3/d)	PEAK FLOW (m^3/d)	BYPASS VOLUME (m^3)	MLSS (mg/L)	MLVSS (%)	RETURN ACTIVATE SLUDGE		WASTE ACTIVATED SLUDGE (m^3/d)	IRON USED (kg)	IRON DOSAGE (mg/L)	SRT (days)	COMMENTS
						(mg/L)	(m^3/d)					
Sept 24	19,000	36,000	1,390	2,965		8,980	6,850	40	21	1.1	7.9	
25	17,640	20,000		3,227		15,226	7,250	50	165	9.4	7.5	
29	12,230	36,000		3,440	68.6	8,040	7,800	90	124	10.1	6.5	Rain - 29.4 mm
30	20,510	36,000	2,700	1,960	75.5	10,580	6,530	450	103	5.0	1.2	Rain - 11.4 mm
Oct. 1	22,740	36,000	4,500	2,420	69.0	9,640	7,880	170	124	5.5	4.1	Rain - 0.2 mm
2	17,710	20,000		2,500	72.8	10,980	5,720	200	103	5.8	3.3	Rain - 1.2 mm
6	16,450	22,000	240	2,120	64.2	7,840	7,030	230	120	7.3	2.1	Rain - 0.2 mm
7	17,150	18,000		2,060	71.8	8,080	7,060	260	103	6.0	2.2	
8	16,240	20,000		1,860	66.7	7,820	7,200	320	83	5.1	1.3	Rain - 1.4 mm
9	16,900	18,000		1,840	78.3	7,280	7,290	360	124	7.3	1.6	
15	15,530	22,000		1,160	72.4	3,640	7,260	590	124	8.4	1.4	Rain - 0.3 mm
16	14,790	20,000		1,160	72.4	3,640	7,260	590	124	8.4	1.4	Rain - 0.3 mm
Average	17,241	25,333	2,208	2,308	71.2	8,749	7,117	263	109	6.6	3.3	
Maximum	22,740	36,000	4,500	3,440	78.3	15,226	7,880	590	165	10.1	7.9	
Minimum	12,230	18,000	240	1,160	64.2	3,640	5,720	40	21	1.1	1.2	

flow are routed through primary treatment and then to chlorination prior to discharge. Twice the flow of the 2.5 times average daily flow can be routed directly to the chlorine contact chamber (no primary treatment) before the plant is hydraulically overloaded.

Although the activated sludge recycle (return) rate was maintained at a relatively constant level during the monitoring period, sludge wasting varied from day-to-day. As a result, the solids retention time (SRT) in the aeration basins was subject to much variation. The relative instability in the biological system along with the high hydraulic loadings resulted in frequent high suspended solids concentrations in the effluent discharged from the plant.

Ferrous chloride addition varied from day-to-day during the monitoring period. The iron content in a sample of the ferrous chloride used during the monitoring period was 129 g/L. The quantity of chemical applied each day averaged 109 kg of iron, and with the exception of one day, ranged from 83 kg up to 165 kg. On one day, a chemical addition of only 21 kg occurred. There was no explanation by plant staff for this non-typical dosage. The average dosage applied was 6.6 mg Fe/L, ranging from 1.1 mg Fe/L to 10.1 mg Fe/L.

The results of the monitoring program are presented in Table 11.5. Raw sewage strength during the monitoring period was low in comparison to historical data (Table 11.2), for all parameters shown in Table 11.5. The influent total phosphorus levels averaged 3.5 mg/L, of which 57 percent was soluble. The main reason for the lower strength of influent raw sewage may be the high rainfall and higher flows observed during the sampling period, relative to historical records.

Effluent quality during the monitoring period was not as good as indicated by historical data. Average effluent BOD_5 was 5.8 mg/L and exceeded 15 mg/L on one occasion, October 15, when the BOD_5 concentration in the effluent was measured as 25 mg/L. The average total suspended solids concentration was, however, much higher in effluent sampled during the monitoring period, than has been historically observed. The average TSS level in secondary effluent during the sampling period was 48.0 mg/L, ranging from 16.0 mg/L to 180.0 mg/L, which is not only higher than historically observed (see Table 11.2) but exceeds MOE discharge guidelines of 25 mg/L. During the monitoring period, a mass of floating reddish-brown sludge mass covered

TABLE 11.5. SUMMARY OF PERFORMANCE MONITORING DATA FOR TRENTON WPCP

DATE	STREAM	CONCENTRATIONS (mg/L)			
		BOD_5	TSS	TOTAL P	SOLUBLE P
24/09	Raw	55.0	70.0	2.92	1.67
	Primary Effluent	-	-	3.85	2.00
	Secondary Effluent	3.0	40.0	3.36	1.84
25/09	Raw	55.0	70.0	3.36	1.84
	Primary Effluent	-	-	2.85	1.68
	Secondary Effluent	3.0	29.0	1.00	0.52
29/09	Raw	70.0	80.0	4.10	2.80
	Primary Effluent	-	-	4.20	2.50
	Secondary Effluent	3.5	70.0	2.50	0.45
30/09	Raw	55.0	80.0	2.60	1.45
	Primary Effluent	-	-	2.10	0.90
	Secondary Effluent	2.0	12.0	1.08	0.31
01/10	Raw	13.0	40.0	2.70	1.73
	Primary Effluent	-	-	4.93	1.56
	Secondary Effluent	1.0	5.0	0.45	0.45
02/10	Raw	-	50.0	3.30	1.97
	Primary Effluent	-	-	2.40	1.38
	Secondary Effluent	1.6	4.0	0.45	0.45
06/10	Raw	70.0	70.0	3.40	2.04
	Primary Effluent	-	-	1.83	1.45
	Secondary Effluent	3.5	40.0	1.10	0.64
07/10	Raw	100.0	80.0	3.40	1.87
	Primary Effluent	-	-	3.40	0.55
	Secondary Effluent	11.0	100.0	2.40	0.45
08/10	Raw	260.0	210.0	5.90	3.40
	Primary Effluent	-	-	2.75	1.23
	Secondary Effluent	7.0	50.0	0.42	0.24
09/10	Raw	110.0	110.0	2.80	1.40
	Primary Effluent	-	-	3.60	1.39
	Secondary Effluent	4.0	30.0	0.62	0.23
15/10	Raw	130.0	110.0	3.60	1.52
	Primary Effluent	-	-	1.95	-
	Secondary Effluent	25.0	180.0	3.60	-
16/10	Raw	103.0	130.0	4.40	2.44
	Primary Effluent	-	-	4.30	1.90
	Secondary Effluent	5.5	16.0	0.49	0.30
AVERAGES	Raw	92.8	91.7	3.54	2.01
	Primary Effluent	-	-	3.18	1.50
	Secondary Effluent	5.8	48.0	1.29	0.41

approximately 75 percent of the secondary clarifier surface area. Plant personnel dispersed the mass with water; the high effluent suspended solids may, thus, be a result of the break up of the sludge mass.

Effluent total phosphorus levels were also high in relation to historical data. The average effluent total phosphorous level observed during the monitoring period was 1.29 mg/L, of which 32 percent was present in the soluble form. Effluent total phosphorus ranged from 0.42 mg/L to 3.60 mg/L and effluent soluble P ranged from 0.23 mg/L to 0.64 mg/L. Probability distributions for total and soluble phosphorus in raw sewage, primary effluent and secondary effluent are presented in Figures 11.2 and 11.3.

Key operating parameters affecting phosphorus removal at the Trenton WPCP are presented in Table 11.6.

The average loading to the secondary clarifiers was relatively high at 42.4 $m^3/m^2 \cdot d$. This high loading, coupled with variable SRTs, may be one reason for the high suspended solids concentration in the secondary effluent (48.0 mg/L). Total phosphorus in the effluent averaged 1.29 mg/L. This result is higher than expected, since the ratio of Fe:P, which averaged 4.6 (by weight), was above the recommended level and produced low effluent soluble phosphorus concentrations. Average soluble phosphorus in the secondary effluent was 0.41 mg/L, and particulate phosphorus was calculated to be 0.88. The standard deviations for total, soluble and particulate phosphorus were calculated as 0.98, 0.12 and 0.68 mg/L, respectively. Thus, it appears that the effluent soluble phosphorus level was relatively stable, while the concentration of total and particulate phosphorus was subject to considerable variation.

11.5 Conclusions of Trenton WPCP Monitoring Program

The monitoring program conducted at the Trenton WPCP produced results which contradicted historical plant performance.

Flows to the plant averaged 17,241 m^3/d, which represented an increase of approximately 66 percent over the previous five year average and 110 percent of plant design capacity.

Total phosphorus discharged in secondary effluent was greater than 1.0 mg/L on all but 2 occasions. The Fe:P ratios were sufficient to reduce soluble phosphorus concentrations to less than 0.5 mg/L. Since soluble phos-

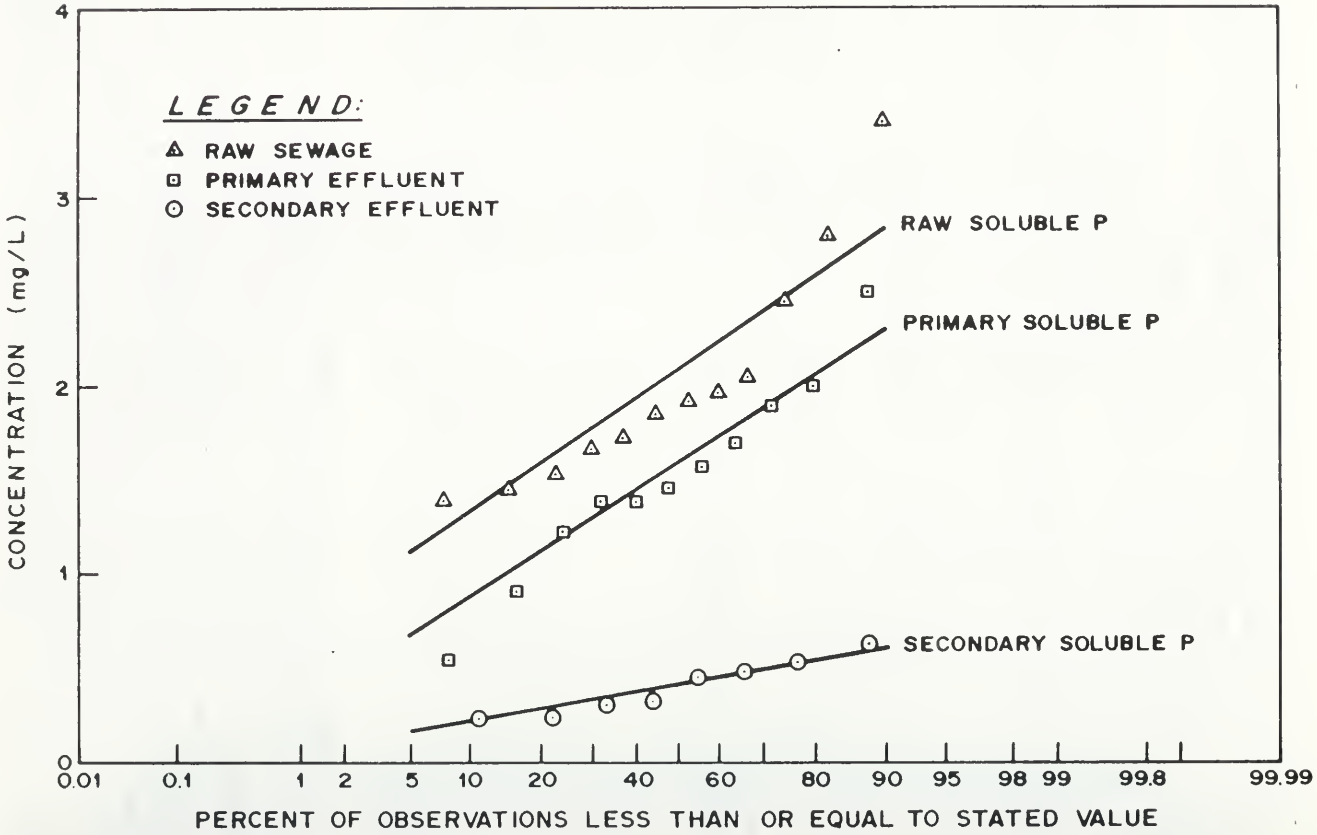


FIGURE 11-3 — SOLUBLE PHOSPHORUS

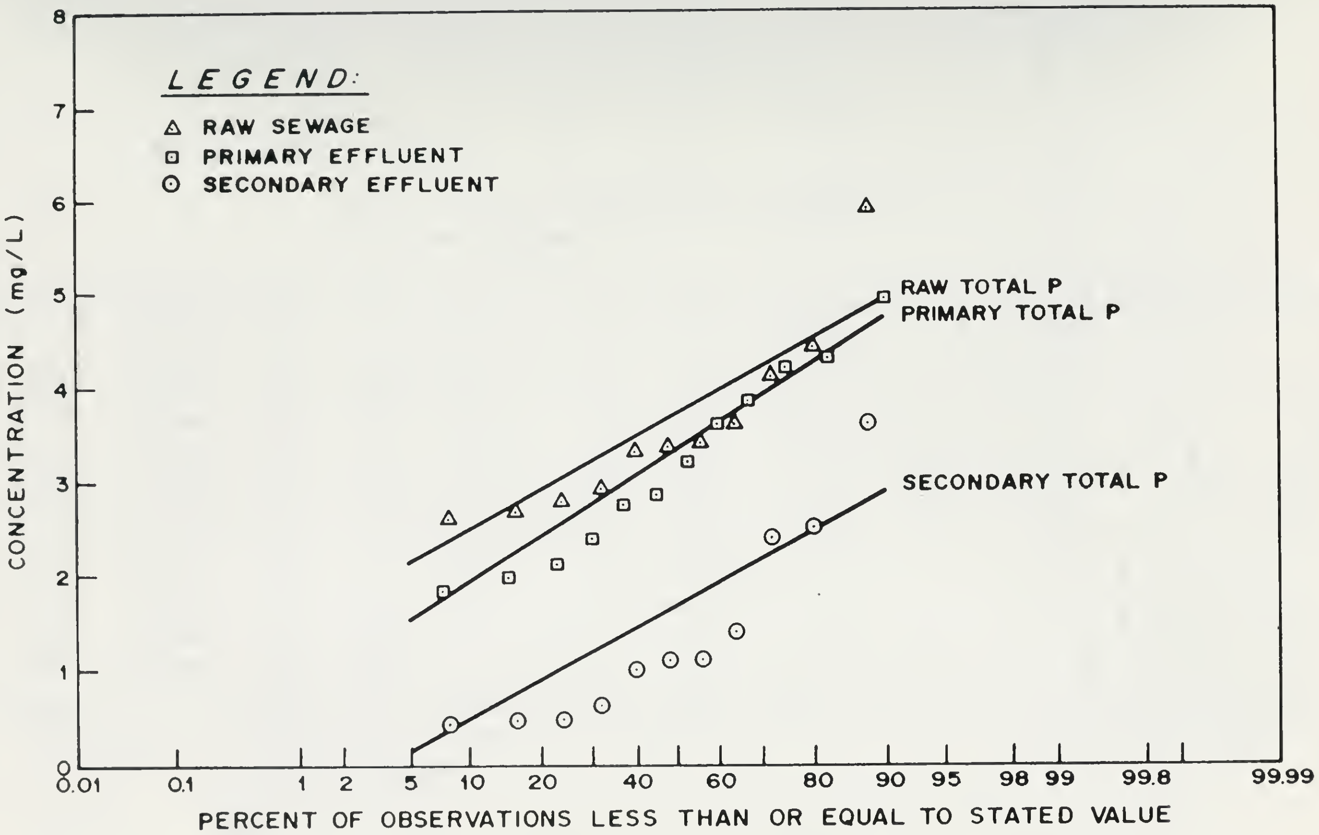


FIGURE 11-2 —PROBABILITY DISTRIBUTIONS FOR PHOSPHORUS AT TRENTON WPCP TOTAL PHOSPHORUS

TABLE 11.6. SUMMARY OF KEY OPERATING PARAMETERS AFFECTING PHOSPHORUS REMOVAL AT TRENTON WPCP

DATE	FLOWS (m^3/d)		CLARIFIER SURFACE LOAD ($m^3/m^2.d$)		IRON (kg)	DOSAGE (mg/L)	SOLUBLE P (mg/L)*	Fe:P** (by wt.)	Fe:P** (molar)	EFFLUENT QUALITY (mg/L)			
	AVERAGE	PEAK	AVERAGE	PEAK						TSS	TOTAL P	SOLUBLE P	PART P
Sept 24	19,000	36,000	46.7	88.5	21	1.1	2.00	0.6	0.3	40	1.39	0.48	0.91
25	17,640	20,000	43.3	49.2	165	9.4	1.68	5.6	3.1	29	1.00	0.52	0.48
29	12,230	36,000	30.1	88.5	124	10.1	2.50	4.1	2.3	70	2.50	0.45	2.05
30	20,510	36,000	50.4	88.5	103	5.0	0.90	5.6	3.1	12	1.08	0.31	0.77
Oct. 1	22,740	36,000	55.9	88.5	124	5.5	1.56	3.5	2.0	5	0.45	0.45	0.00
2	17,710	20,000	43.5	49.2	103	5.8	1.38	4.2	2.3	4	0.45	0.45	0.00
6	16,450	22,000	40.5	54.1	120	7.3	1.45	5.0	2.8	40	1.10	0.64	0.46
7	17,150	18,000	42.2	44.2	103	6.0	0.55	10.9	6.1	100	2.40	0.45	1.95
8	16,240	20,000	39.9	49.2	83	5.1	1.23	4.2	2.3	50	0.42	0.24	0.18
9	16,900	18,000	41.5	44.2	124	7.3	1.39	5.3	2.9	30	0.62	0.23	0.39
15	15,530	22,000	38.2	54.1	118	7.6	-	-	-	180	3.60	-	-
16	14,790	20,000	36.3	49.2	124	8.4	1.90	4.4	2.5	16	0.49	0.30	0.19
Average	17,241	25,333	42.4	62.3	109	6.6	1.50	4.9	2.6	48	1.29	0.41	0.88

* In primary effluent.

** Based on primary effluent soluble phosphorus.

phorus levels were relatively constant, high total phosphorus concentrations were typically due to particuate phosphorus concentrations resulting from high suspended solids levels in effluents. Poor suspended solids removal in the secondary clarifier could be attributed to the high clarifier hydraulic loading during the monitoring period and general plant instability indicated by highly variable and low solids retention times.

12.0 ESTEN LAKE (ELLIOT LAKE) WATER POLLUTION CONTROL PLANT

12.1 Plant Description and Historical Performance

12.1.1 Plant Description

The Esten Lake WPCP serves the Town of Elliot Lake. The plant, which is operated by the Town, is a conventional activated sludge plant designed to handle an average daily flow of 16,000 m^3/d (3.52 MIGPD) with a peak hydraulic load of 42,000 m^3/d (9.24 MIGPD). A schematic flowsheet of the plant is provided in Figure 12.1. Key design parameters for the Esten Lake WPCP are summarized in Table 12.1.

Raw sewage is lifted into the plant using three helical screw (Archimedes) pumps. Each pump is rated for 0.3 m^3/s. Pretreatment is provided by a mechanical bar screen upstream of two parallel 15 m^2 aerated grit tanks each having a depth of 3.0 m.

Three parallel clarifiers, each 28.7 m by 7.0 m with a liquid depth of 3.25 m, provide a total surface area of 600 m^2 for primary sedimentation. Total primary clarifier volume is approximately 1,960 m^3. The clarifiers were sized based on a surface loading rate of 24 $m^3/m^2 \cdot d$. Raw sludge and scum removal are accomplished by flight-and-chain scraper/skimmer mechanisms. Waste activated sludge from the biological system is co-thickened with primary sludge in the primary clarifiers.

Biological treatment is accomplished in two parallel completely mixed aeration tanks. Each tank is 17 m square and 3.9 m deep, providing a total aeration volume of 2,250 m^3. Oxygen transfer is accomplished using four two-speed (15/7.5 kW) mechanical surface aerators in each tank. Draft tubes are not used. Total installed aeration capacity is approximately 120 kW (160 HP). Primary effluent is distributed equally to each aeration tank to an entry point in the centre of each tank. Return activated sludge is mixed with primary effluent in the aeration tank feed distribution chamber.

Phosphorus removal is accomplished by alum addition to the mixed liquor in the secondary clarifier distribution chamber upstream of the two secondary clarifiers. A mechanical mixer is provided at the point of alum, addition; however, this supplemental mixer is not presently used. Alum is delivered by two chemical metering pumps from two 46.0 m^3 storage tanks to the addition point. At present the alum feed rate is adjusted manually; however, efforts are being made to automate the alum addition rate.

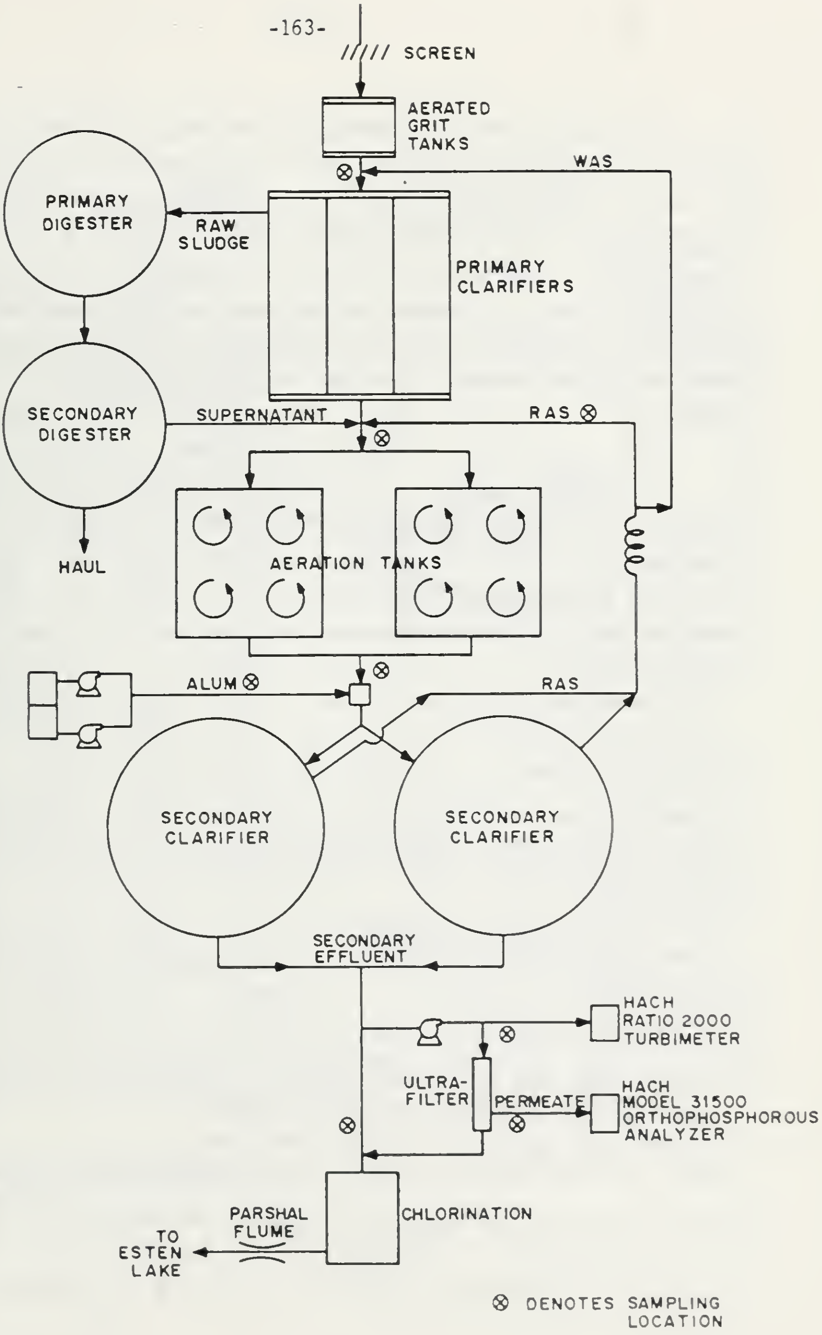


FIGURE 12-1 : SCHEMATIC FLOWSHEET OF ESTEN (ELLIOT LAKE) WPCP

TABLE 12.1: DESIGN SUMMARY - ESTEN LAKE (ELLIOT LAKE) WPCP

DESIGN CRITERIA	STAGE 2 DESIGN VALUE	OPERATING * LEVEL
Flow - m^3/d		
Average Daily	16,000	10,400
Peak Day	432,000	est 18,180
BOD_5 Loading (kg/d)	3,200	1,142
Sewer Collection System	100% Separate	--
Bypass - Point	Inf. Wet Well & After Primaries	--
Frequency	--	0/year
Discharge Point	Outfall	--
Primary Clarification HRT (hours)		
HRT (hours)	2.9	5.5
Average Surface Load ($m^3/m^2 \cdot d$)	26.7	14.0
Peak Surface Load ($m^3/m^2 \cdot d$)	70.0	38.8
Aeration System		
HRT (hours)	3.4	5.2/2.6†
BOD_5 Load ($kg/m^3 \cdot d$)**	--	0.30/0.61††
Return Sludge Rate (%)	81	--
Phosphorus Removal		
Chemical	Alum	--
Average Dosage (mg Al/L) (based on alum concentration of 4.37% Al)	--	1983=3.43mg/L 1985=2.67mg/L
Secondary Clarification		
HRT (hours)	5.3	8.2
Avg. Surface Loading ($m^3/m^2 \cdot d$)	15.2	9.8
Peak Surface Loading ($m^3/m^2 \cdot d$)	40.0	17.2
Chlorination		
HRT @ Peak Flow (min)	--	--

* Based on 1982-1985 Historical Data (plant started up in late 1981).

** At 40 percent primary clarifier BOD removal.

† HRT with both/one aeration tanks in service.

†† BOD_5 load with both/one aeration tanks in service.

The Esten Lake plant was the only plant evaluated in this study attempting to use a continuous on-line analyzer to measure the final effluent phosphorus concentration to control the chemical (alum) addition rate. The analyzer used was a Hach Model 31500 orthophosphate analyzer. The instrument uses the colourimetric vandomolybdophosphoric acid method. At the time of this investigation, the plant was in the process of evaluating various methods of conditioning the colourimeter feed sample based on in-line sample filtration. Plugging of the filters used was reported to be a persistent problem. Feedback control of the alum dosage had not been implemented. Based on experience with other methods of sample conditioning, CANVIRO provided an Abcor 5-HFM-220 tubular ultrafilter for sample conditioning. This unit successfully provided a continuous solids-free sample to the orthophosphate analyzer. A Hach Ratio 2000 Turbidimeter was installed to measure the turbidity of the unconditioned effluent stream. This measurement was planned to be used to empirically estimate the effluent particulate total phosphorus concentration. The plan proposed by the plant was to ratio the alum dose to the predicted aeration basin total effluent phosphorus concentration.

Secondary clarification is accomplished in two parallel 26 m diameter circular centre-feed clarifiers providing a total surface area of 1,060 m^2 and a total liquid volume of 3,540 m^3. The sludge removal mechanisms are rotating scrapers with centre collection and drawoff. Return sludge is handled by two helical (Archimedes) screw pumps, each transferring 4.56 m^3/min and providing 81 percent recycle sludge capability at design (Stage 2) flow. Secondary effluent is chlorinated prior to discharge to Esten Lake.

Two-stage anaerobic digestion is provided for waste activated sludge and primary sludge. One primary digester provides a volume of 2,385 m^3. The secondary digester provides a volume of 2,315 m^3. Digested sludge is disposed by truck to sludge storage lagoons located 8 km distant.

12.1.2 Historical Performance

Table 12.2 summarizes the annual performance of the Esten Lake WPCP for the years 1982 to 1985. The plant has achieved a high quality effluent, averaging approximately 13 mg/L total BOD_5, suspended solids and total

TABLE 12.2: ANNUAL AVERAGE PERFORMANCE OF ESTEN LAKE (ELLIOT LAKE) WPCP

PARAMETER	YEAR				5 YEAR AVERAGE 82-85
	1982	1983	1984	1985	
Average Daily Flow (1,000 m^3/d)	9.66	9.66	10.93	12.50	10.40
BOD_5 - Influent (mg/L)	137.6	137.6	111.7	87.1	109.8
BOD_5 - Effluent (mg/L)	13.8	12.5	7.9	15.3	12.6
TSS - Influent (mg/L)	119.9	104.0	128.9	117.2	117.5
TSS - Effluent (mg/L)	11.6	9.8	12.3	15.9	12.4
Total P - Influent (mg/L)	1.98	2.35	5.33	14.88	3.63
Total P - Effluent (mg/L)	0.77	0.67	1.33	1.10	0.97

phosphorus for the four-year period (1982 - 1985). Influent strength has been relatively low (110 mg/L BOD_5, 117 mg/L suspended solids and 3.6 mg/L total phosphorus). Average daily flow to the plant for the four-year period was 10,400 m^3/d (65 percent of design flow).

Monthly effluent quality data for 1984 and 1985 (BOD_5, suspended solids and total phosphorus) are presented in Table 12.3. Effluent phosphorus levels have frequently exceeded the target value of 1.0 mg/L with a maximum monthly value of 3.1 mg/L for November, 1984. Equipment problems prevented alum addition for about 60% of the time in 1984. Effluent suspended solids exceeded 15 mg/L for ten of the 24 months but never exceeded 25 mg/L. Effluent BOD_5 exceeded 15 mg/L for six months and exceeded 25 mg/L for two months during this period. Sludge haulage and storage problems were reported for the period from October, 1984 to March, 1985. Extra sludge storage lagoon capacity and clean-out of the existing lagoons was noted to be a problem.

12.1.3 Sampling Program

The Esten Lake WPCP was sampled between July 22, 1986 and August 22, 1986. Twelve daily samples were collected during this monitoring period.

Sampling locations were identified in Figure 12.1. Twenty-four hour composite samples of raw wastewater (after screening) and primary effluent were collected. Flow-proportional, 24-hour composite samples of secondary effluent (before chlorination) were collected. Grab samples of mixed liquor and return sludge were collected to allow SRT calculations to be completed. Grab samples of the ultrafilter permeate were also collected for total phosphorus and ortho phosphorus analysis for comparison to the Hach analysis.

12.2 Results of Sampling Program

Table 12.4 presents a compilation of plant operating data for the five-week period of sampling at the Esten Lake WPCP. Average daily flow for this period, which included several rainfall events, was 8,490 m^3/d or 53 percent of plant design. This flow was significantly lower than observed during 1985 (12,500 m^3/d or 78 percent of design). Peak flows as high as 23,833 were observed during this period.

TABLE 12.3: MONTHLY AVERAGE PERFORMANCE OF ESTEN LAKE (ELLIOT LAKE) WPCP

YEAR	MONTH	EFFLUENT BOD$_5$ (mg/L)	n BOD$_5$	EFFLUENT TSS (mg/L)	n TSS	EFFLUENT TP (mg/L)	n TP
1984	Jan.	6.1	1	11.8	9	0.49	85
	Feb.	6.1	1	15.4	8	0.22	-
	Mar.	7.6	1	11.8	9	0.25	82
	Apr.	22.0	1	9.6	8	0.10	-
	May	-	-	9.0	8	0.15	-
	June	1.4	1	5.3	8	0.35	-
	July	3.3	1	7.1	10	2.75	-
	Aug.	2.9	1	10.0	10	1.75	-
	Sept.	3.4	1	6.7	7	2.00	-
	Oct.	2.0	1	13.3	10	1.85	-
	Nov.	-	-	23.9	8	3.10	-
	Dec.	23.8	1	22.9	7	2.95	-
1985	Jan.	62.0	1	22.1	10	2.32	10
	Feb.	22.0	1	19.1	11	1.10	12
	Mar.	10.9	1	16.9	8	1.10	8
	Apr.	9.1	1	22.8	8	1.01	9
	May	10.2	1	11.2	14	0.83	10
	June	29.0	1	11.5	11	1.08	11
	July	4.2	1	11.9	15	0.90	15
	Aug.	2.6	1	13.3	12	0.81	11
	Sept.	4.6	1	9.0	14	0.94	14
	Oct.	5.6	1	16.9	18	1.11	18
	Nov.	19.0	1	18.3	17	1.06	17
	Dec.	4.8	1	18.3	18	0.95	17

n = Number of samples

TABLE 12.4: PLANT SUMMARY OF ESTEN LAKE (ELLIOT LAKE) WPCP OPERATING CONDITIONS (JULY 22 - August 22, 1986)

DATE (1986)	FLOW ($m^3/d \times 10^3$)			BYPASS (HR)	MLSS (mg/L)	MLVSS (%)	RAS (mg/L)	WAS (m^3)	ALUM* (L/d)	Al DOSAGE* (mg/L)	SRT** (days)	COMMENT
	TOTAL	MAX.	MIN.									
July 22	7410	11263	3557	0	2484	59.0	3864	80	309	1.83	7.0	
23	7280	11066	3494	0	2924	58.5	4156	250	309	1.85	3.1	
24	6273	9535	3011	0	2528	61.6	4620	545	309	2.15	1.1	
25	7180	10914	3440	0	2598	58.7	5204	790	309	1.88	0.7	
26	6777	11656	2982	0	--	--	--	557	257	1.66	--	
27	6777	10572	2982	0	--	--	--	557	257	1.66	--	
28	6777	11656	2982	0	2296	--	--	557	257	1.66	--	
29	15680	23833	11290	0	3000	58.2	5964	820	309	0.86	0.7	
30	10580	16082	6771	0	2514	58.0	--	750	154	0.64	--	
31	9960	15139	6374	0	3226	56.9	7080	700	309	1.35	0.7	
Aug. 1	7450	9462	2384	0	2874	--	--	--	--	--	0.7	
2	7573	14237	--	0	--	--	--	818	270	1.56	--	
3	7573	13328	--	0	--	--	--	818	270	1.56	--	
4	7573	11814	--	0	--	--	--	818	270	1.56	--	
5	7573	12117	--	0	--	--	--	818	270	1.56	--	
6	8070	10249	4842	0	2482	56.5	4588	760	309	1.68	--	
7	8543	10850	3142	0	2472	58.7	4232	740	309	1.58	0.9	Primary #3 Down
8	7079	8990	3009	0	2626	60.6	5068	1094	154	0.95	0.5	
9	10654	17311	5479	0	--	--	--	740	154	0.64	--	
10	10654	16740	6087	0	--	--	--	740	154	0.64	--	
11	11893	14628	7136	0	2282	61.0	4612	740	232	0.85	0.7	
12	11040	16250	7066	0	--	--	--	750	309	1.23	--	
13	8580	10897	4576	0	2334	62.7	4416	740	309	1.58	0.8	
14	8810	11189	3524	0	--	--	--	680	309	1.54	--	
15	8610	10935	5166	0	2338	61.5	3960	910	309	1.56	0.7	
16	8050	15456	3864	0	--	--	--	607	257	1.40	--	
17	8050	15456	4186	0	--	--	--	607	257	1.40	--	
18	8050	20286	1610	0	--	--	--	607	257	1.40	--	Aeration Tanks Switched
19	8140	20513	2930	0	2200	63.0	3636	840	309	1.66	0.8	
20	7930	10071	4124	0	1108	65.0	2052	790	309	1.70	0.7	
21	7790	9893	4124	0	1270	63.6	2048	0	309	1.74	18.4	
22	7351	9336	4379	0	1630	62.8	2740	6	309	1.84	52.8	
AVG.	8490	--	--	-	2380	60.4	4265	653	271	1.46	--	
MAX.	15680	23833	7136	0	3226	65.0	7080	1094		2.15	52.8	
MIN.	6273	8990	1610	0	1108	56.5	2048	0		0.64	0.5	

*Alum concentration of 43.7 kg Al/m^3

**SRT based on one aeration tank in service.

The biological system was operated with a relatively low sludge age. Solids retention time (SRT) was usually less than 1 day (Table 12.4) with a few high values on days with little waste activated sludge. Historical data for 1985 has shown that the plant achieved only a small degree of nitrification consistent with the low SRT observed. Influent TKN concentrations averaged 22.6 mg/L in 1985. Average effluent TKN was 14.4 mg/L and average effluent NH_3-N was 12.7 mg/L for the same period.

Alum was added at an average rate of 271 L/d throughout the monitoring period. Samples from two batches of alum showed an average aluminum (Al) content of 34.95 g/L. The actual alum concentration was considered to be 43.7 g Al/L for calculation of the dosage rate. The calculated chemical dosage was relatively low and averaged 1.46 mg Al/L for the 5-week period, ranging from 0.64 mg/L to 2.15 mg/L.

The results of the monitoring program are summarized in Table 12.5. Results reported by the plant and by CANVIRO showed that raw wastewater strength, in terms of all parameters, was low compared to historical data. Based on the CANVIRO data, the raw wastewater averaged 46 mg/L BOD_5 and 50 mg/L suspended solids. Influent total phosphorus levels averaged 3.09 mg/L, of which approximately 65 percent was presented in soluble form. The strength was lower than the strength indicated by the historical data. Effluent quality during the monitoring period showed good performance for BOD_5 and SS removal. Average effluent BOD_5 was 4 mg/L. Average effluent suspended solids concentration was 8 mg/L. Based on CANVIRO data, total phosphorus in the secondary effluent was 0.82 mg/L, of which 0.54 mg/L was present in soluble form. Probability distributions of the total and soluble components of the phosphorus in raw sewage, primary effluent and secondary effluent are presented in Figure 12.2. Primary clarification did not significantly reduce the total phosphorus concentration.

Key operating parameters affecting phosphorus removal at the Esten Lake WPCP are summarized in Table 12.7. Clarifier hydraulic loadings were low, averaging approximately 8 $m^3/m^2 \cdot d$ (165 Igpd/ft^2). The low hydraulic loading, along with good sludge settleability (SVI <77), produced low effluent suspended solids concentrations. Thus, phosphorus associated with the particulate matter in the effluent contributed only 0.28 mg/L to the total phosphorus concentration. Based on soluble phosphorus in the primary effluent, the average Al:P molar ratio was 1.1, compared to the stoichio-

DATE	STREAM	CONCENTRATION (mg/L)										
		CANVIRO ANALYSES				ESTEN LAKE PLANT ANALYSES				ULTRAFILTER		
		TOTAL BOD_5	TSS	TOTAL PHOSPHOROUS	SOLUBLE PHOSPHOROUS	TSS	TOTAL PHOSPHORUS	SOLUBLE PHOSPHORUS	ORTHO PHOSPHORUS	TOTAL PHOSPHORUS		ORTHO PHOSPHORUS
										CANVIRO	ESTEN LAKE	ESTEN LAKE
22-23/ 07	Raw	40	20	2.74	--	57	3.2	0.8				
	Primary Effluent	-	-	2.13	0.68	25	2.63	0.65				
	Secondary Effluent	4	11	0.71	<0.20	5	0.65		0.15	<0.20	0.10	0.08
23-24/ 07	Raw	40	60	2.70	1.53	59	2.8	1.4				
	Primary Effluent	-	-	3.05	1.60	39	2.9	1.5				
	Secondary Effluent	4	7	0.38	<0.23	6	0.47		6	<0.20	0.13	0.04
24-25/ 07	Raw	45	50	2.94	1.96	52	3.0	1.9				
	Primary Effluent	-	-	8.06	1.70	114	6.3	1.6				
	Secondary Effluent	3	3	0.28	<0.20	4	0.38		0.10	<0.20	0.01	0.10
05-06/ 08	Raw	63	80	3.40	2.47	59	3.0	1.4				
	Primary Effluent	-	-	3.87	2.45	45	2.9	1.3				
	Secondary Effluent	4	11	0.57	0.44	10	1.05		0.47	0.26	0.38	0.30
06-07/ 08	Raw	50	60	3.40	2.50	72	2.6	2.1				
	Primary Effluent	-	-	--	2.39	75	4.3	2.2				
	Secondary Effluent	3	3	1.25	0.74	7	1.00		0.60	0.46	0.50	0.35
07-08/ 08	Raw	45	40	3.90	2.80	71	4.25	2.87				
	Primary Effluent	-	-	3.25	2.00	43	3.75	2.25				
	Secondary Effluent	2.5	6	1.05	0.78	8	1.13		0.67	0.28	0.45	0.43
10-11/ 08	Raw	41	40	2.50	1.53	56	2.6	2.0				
	Primary Effluent	-	-	2.08	1.58	39	3.8	1.9				
	Secondary Effluent	3	7	0.96	0.68	5	0.8		0.53	0.31	0.42	0.38
12-13/ 08	Raw	33	50	2.94	1.60	52	3.3	2.1				
	Primary Effluent	-	-	2.90	1.91	53	4.3	1.8				
	Secondary Effluent	3	4	0.93	0.59	6	0.92		0.53	0.66	0.45	0.45
14-15/ 08	Raw	32	30	3.00	2.08	75	3.6	2.7				
	Primary Effluent	-	-	2.20	1.55	32	2.4	1.8				
	Secondary Effluent	3	7	0.68	0.58	9	0.95		0.43	0.39	0.42	0.38
19-20/ 08	Raw	48	80	3.10	1.37	176	3.8	1.4				
	Primary Effluent	-	-	3.45	2.38	26	2.7	2.4				
	Secondary Effluent	7	13	1.30	0.70	13	1.5		0.60	0.44	0.47	0.43
20-21/ 08	Raw	61	50	3.16	2.15	76	3.80	3.40				
	Primary Effluent	-	-	2.90	2.24	46	2.60	2.3				
	Secondary Effluent	6	9	0.93	0.72	10	1.6		0.6	0.46	1.13	0.43
21-22/ 08	Raw	52	50	3.30	2.16	77	3.8	2.5				
	Primary Effluent	-	-	.60	2.20	33	3.1	2.0				
	Secondary Effluent	4	8	0.80	0.61	3	1.05		0.50	0.53	0.45	0.48
AVERAGES	Raw	46	50	3.09	<2.01	74	3.3	2.1				
	Primary Effluent	-	-	3.30	1.89	48	3.47	1.8				
	Secondary Effluent	4	8	0.82	0.54	8	0.96		0.45	0.37	0.41	0.32
Std.Devs	Raw	0	18	0.38	<0.47	34	0.54	0.7				
	Primary Effluent	-	-	1.77	0.51	25	1.11	0.5				
	Secondary Effluent	1	3	0.32	0.22	3	0.36		0.19	0.15	0.28	0.16

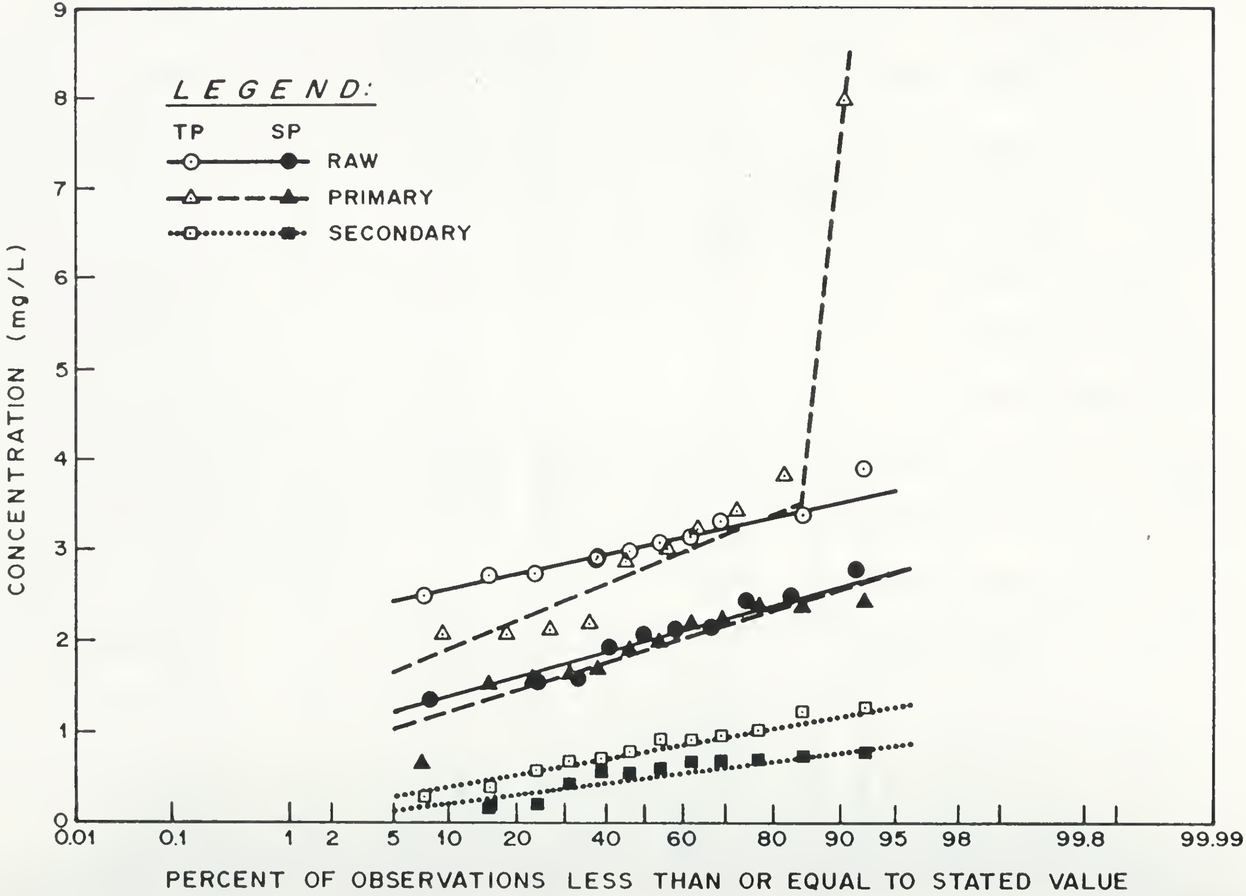


FIGURE 12-2: PROBABILITY DISTRIBUTIONS FOR PHOSPHOROUS DATA AT THE ESTENLAKE (ELLIOT LAKE) WPCP

TABLE 12.6: SUMMARY OF PERFORMANCE RESULTS FOR HACH MODEL 13500 ORTHO PHOSPHORUS AND RATIO 2000 TURBIMETER ANALYZERS

DATE	CONCENTRATION (mg/L)					
	ULTRAFILTERED ORTHO PHOSPHORUS	ANALYZER ORTHO PHOSPHORUS	TOTAL P*	PART. P	TURBIDITY	SUSPENDED SOLIDS
25/08	0.19	0.21	0.80	0.59	-	11
	0.16	0.23	0.95	0.72	-	11
	0.16	0.17	0.90	0.73	-	8.5
	0.17	0.17	0.90	0.73	-	7.5
	0.19	0.16	0.87	0.71	-	8
26/08	0.20	0.22	1.10	0.88	6.0	10.5
	0.23	0.20	1.10	0.90	6.1	8.5
	0.23	0.23	0.83	0.60	6.1	6.5
	0.23	0.23	1.10	0.87	6.0	9.5
	0.24	0.23	0.90	0.67	5.9	6.0
	0.23	0.23	0.92	0.69	5.7	8.5
	0.23	0.23	0.85	0.62	5.9	9.5
27/08	0.70	0.60	2.1	1.50	4.9	7.5
	0.77	0.60	1.4	0.80	4.5	7.0
	0.80	0.82	1.5	0.68	4.2	3.5
28/08	1.13	1.23	1.7	0.47	3.6	4
29/08	0.37	0.37	1.10	0.73	5.8	9.5
	0.34	0.34	1.05	0.71	5.5	8.0
	0.35	0.36	1.00	0.64	7.0	5.5
	0.34	0.35	0.95	0.60	11.8	9.5
	0.34	0.34	0.95	0.61	5.8	5.0
02/09	0.26	0.34	0.52	0.18	8.2	8
	0.27	0.27	1.16	0.83	6.7	6.5
	0.28	0.27	1.10	0.83	13.8	9.5
	0.27	0.26	0.90	0.64	6.2	6.5
	0.28	0.28	0.77	0.49	4.5	3.0
03/09	0.22	0.21	0.77	0.56	6	4.5
04/09	0.23	0.20	0.80	0.60	4.5	5
	0.23	0.23	0.83	0.60	2.0	5
	0.24	0.24	0.68	0.44	3.0	2
05/09	0.13	0.11	0.68	0.57	6	8
	0.10	0.10	0.42	0.32	2	3.5

*Total phosphorus is unfiltered sample (grab).

TABLE 12.7: SUMMARY OF KEY OPERATING PARAMETERS FOR THE ESTEN LAKE (ELLIOT LAKE) WPCP

DATE (1986)	FLOW (10^3 m^3/d)		CLARIFIER LOAD ($m^3/m^2 \cdot d$)		Al DOSE (mg/L)	PRIMARY CLAR. SOL. P. (mg/L)	Al:P RATIO*		EFFLUENT QUALITY (mg/L)			
	AVERAGE	PEAK	AVERAGE	PEAK			WEIGHT	MOLAR	TSS	TP	SOL.P.	PART.P.
22/07	7.41	11.26	6.99	10.62	1.83	0.68	2.69	3.09	11	0.71	<0.20	0.51†
23/07	7.28	11.07	6.87	10.44	1.85	1.60	1.16	1.33	7	0.38	<0.23	0.15†
24/07	6.27	9.54	5.92	9.00	2.15	1.70	1.26	1.45	3	0.28	<0.20	0.08†
05/08	7.57	12.12	7.14	11.43	1.56	2.45	0.64	0.73	11	0.57	0.44	0.13
06/08	8.07	10.25	7.61	9.67	1.68	2.39	0.70	0.80	8	1.25	0.74	0.51
07/08	8.54	10.85	8.06	10.24	1.58	2.00	0.79	0.91	6	1.05	0.78	0.27
10/08	10.65	16.74	10.05	15.79	0.64	1.58	0.41	0.47	7	0.96	0.68	0.28
12/08	11.04	16.25	10.42	15.33	1.23	1.91	0.64	0.73	4	0.93	0.59	0.34
14/08	8.81	11.19	8.31	10.56	1.54	1.55	0.99	1.14	7	0.68	0.58	0.10
19/08	8.14	20.51	7.68	19.35	1.66	2.38	0.70	0.80	13	1.30	0.70	0.60
20/08	7.93	10.07	7.48	9.50	1.70	2.24	0.76	0.87	9	0.93	0.72	0.21
21/08	7.79	9.89	7.35	9.33	1.74	2.20	0.79	0.91	8	0.80	0.61	0.19
AVERAGE	8.29	12.48	7.82	11.77	1.60	1.89	0.96	1.10	8	0.82	0.54	0.28†

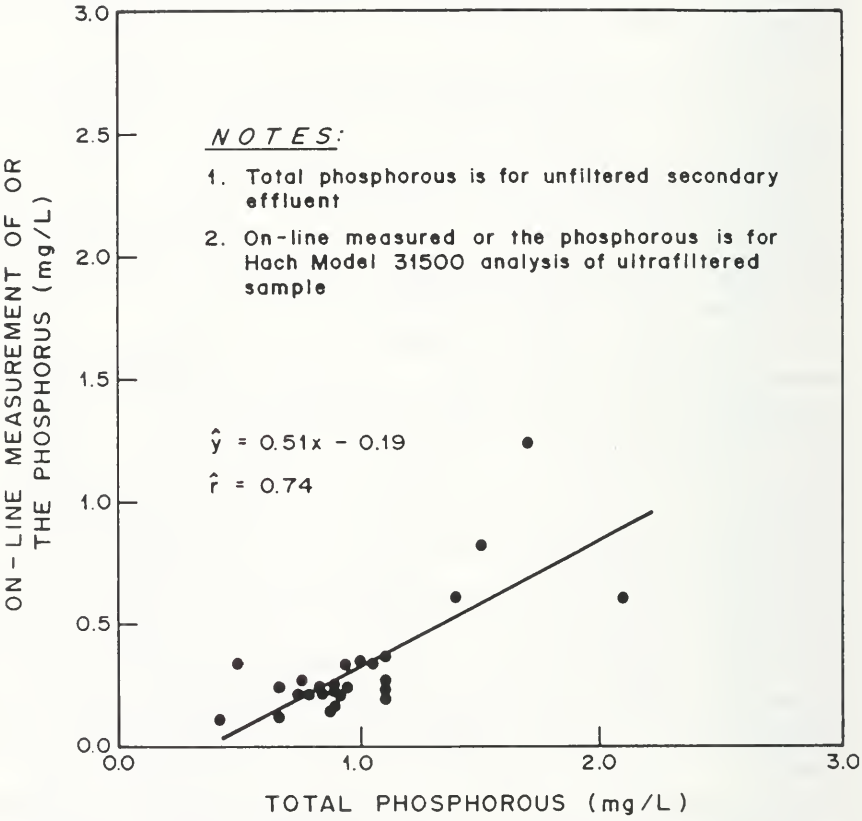
*Based on primary effluent soluble phosphorus concentration.
†Estimated value

metric requirement of 1. Thus, the chemical dosage, which averaged 1.60 mg Al/L, was sufficient to result in a low soluble phosphorus concentration (0.54 mg/L based on CANVIRO data) in the secondary effluent. However, on three occasions the total phosphorus in the effluent exceeded 1.0 mg/L with a maximum of 1.30 mg/L. The average total phosphorus in the secondary effluent was 0.82 mg/L.

The Esten Lake plant staff duplicated the analyses performed by CANVIRO for total suspended solids and total phosphorus. Samples for total phosphorus were digested before analysis using a Hach kit. The plant also provided a measurement of the orthophosphate concentration of the secondary clarifier effluent. Based on the plant data, average effluent suspended solids was also reported to be 8 mg/L. Effluent total and orthophosphorus were 0.96 mg/L and 0.45 mg/L, respectively.

The Abcor ultrafilter permeate was analyzed for total and ortho phosphorus concentration (Table 12.5). The average permeate total phosphorus concentration was 0.37 mg P/L based on CANVIRO analyses. The Esten Lake analysis for total phosphorus in the permeate (average value 0.41 mg P/L) was consistent with CANVIRO's estimate. The ortho phosphorus concentration averaged 0.32 mg P/L which was about 70 percent of the value of 0.34 mg P/L based on the standard Whatman glass fibre (GF/C) filtration procedure. The ultrafilter performed well during the investigation and provided a turbidity-free sample for analysis using the on-line Hach analyzer. Usage of the ultrafilter to obtain a permeate directly from the mixed liquor should be evaluated. This would eliminate the long lag time due to the secondary clarifiers and improve control of the alum dosage pumps when feedback control is established.

Based on data provided by the plant staff after the completion of the CANVIRO sampling program, it was determined that the on-line Hach ortho phosphorus analyzer agreed closely with off-line samples of permeate analyzed for orthophosphorus. There was no statistical difference between the on-line measurement and grab samples of permeate collected for ortho phosphorus analyses based on a paired-data comparison. The maximum difference reported was 0.17 mg/L which occurred during a period without alum addition. Table 12.6 summarizes the results of the analyzer performance evaluation carried out by the plant staff between August 25 and September 5, 1986. Figure 12.3



NOTES:

1. Total phosphorous is for unfiltered secondary effluent
2. On-line measured or the phosphorous is for Hach Model 31500 analysis of ultrafiltered sample

FIGURE 12-3: RELATIONSHIP BETWEEN SECONDARY EFFLUENT ORTHO PHOSPHOROUS (ULTRAFILTERED) AND TOTAL PHOSPHOROUS FOR THE ESTEN LAKE WPCP

shows the relationship between the on-line analyses for orthophosphorus and total phosphorus measured in grab samples of the unfiltered effluent. The data cover a relatively narrow range; however, there is evidence of a correlation between the two results.

Based on these data (Figure 12.3), it is evident that a secondary effluent ultrafiltered orthophosphorus concentration of about 0.32 mg/L is required to obtain a final effluent total phosphorus of 1.0 mg/L.

Secondary effluent particulate phosphorus concentration appeared to be correlated to the effluent turbidity as measured by the turbidimeter. Figure 12.4 shows the relationship between the particulate phosphorus and turbidity. There was considerable scatter in these data; however, measurements of turbidity are difficult at the low concentration reported. Removal of particulate phosphorus is dependent primarily on effective clarification of the mixed liquor. Unlike particulate phosphorus, there was not a significant relationship between effluent total phosphorus and effluent SS or turbidity based on the grab samples collected. For a secondary effluent total phosphorus concentration of 1.0 mg/L (0.32 mg/L soluble phosphorus plus 0.68 mg/L particulate phosphorus), an effluent turbidity of about 6 mg/L would be required. Figure 12.5 shows the relationship between effluent particulate phosphorus and effluent gravimetric suspended solids. The degree of correlation is similar to that for the turbidity relationship (Figure 12.4); however, fewer outlines are evident. For an effluent total phosphorous concentration of 1.0 mg/L (0.32 soluble; 0.68 particulate), the effluent suspended solids concentration should be less than about 8 mg/L. This indicates that a consistently high quality secondary effluent is required to meet the MOE guideline of 1.0 mg/L total phosphorous in the effluent at the Esten Lake WPCP. During the sampling program, the secondary clarifier effluent SS averaged 8 mg/L.

Control of alum dosage likely would be best achieved by measurement of the ultrafiltered orthophosphorus concentration alone due to the relationship between precipitation of the soluble component and chemical dosage. Effluent particulate phosphorus is more dependent on secondary clarifier operation and control.

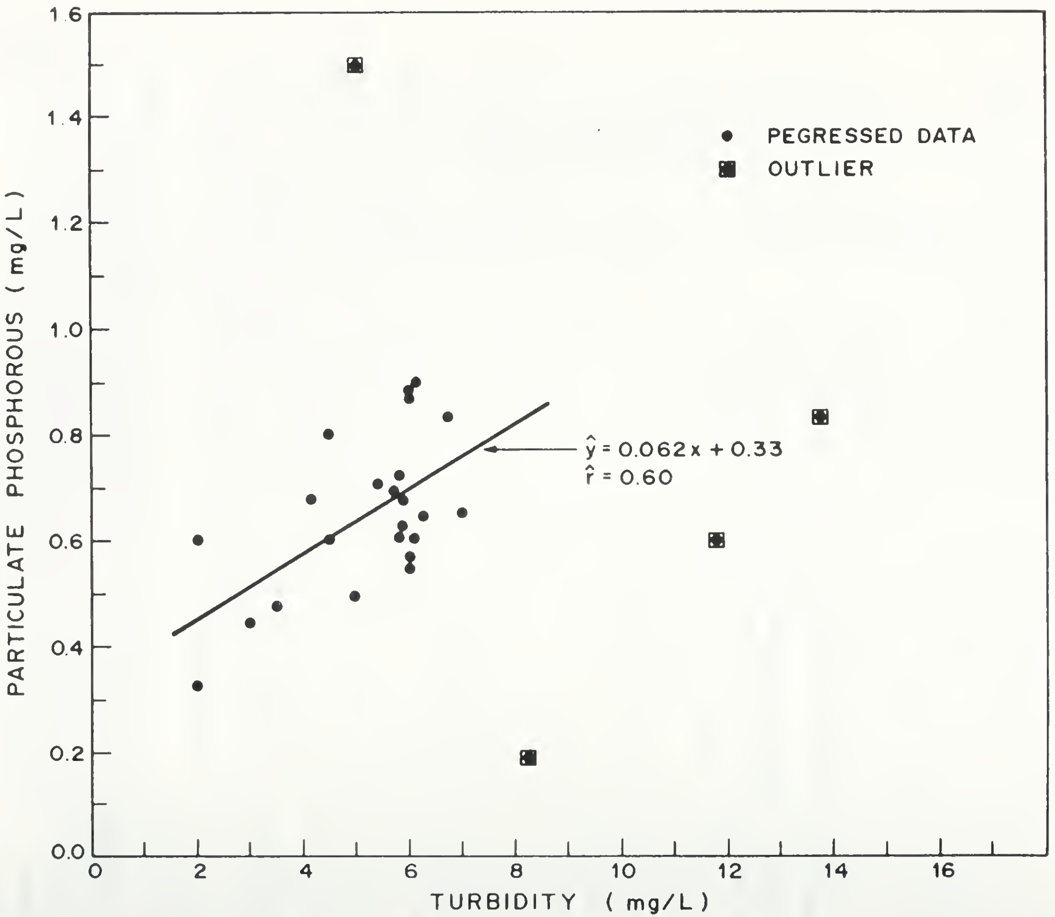


FIGURE 12-4 : RELATIONSHIP BETWEEN SECONDARY EFFLUENT PARTICULATE PHOSPHOROUS AND TURBIDITY

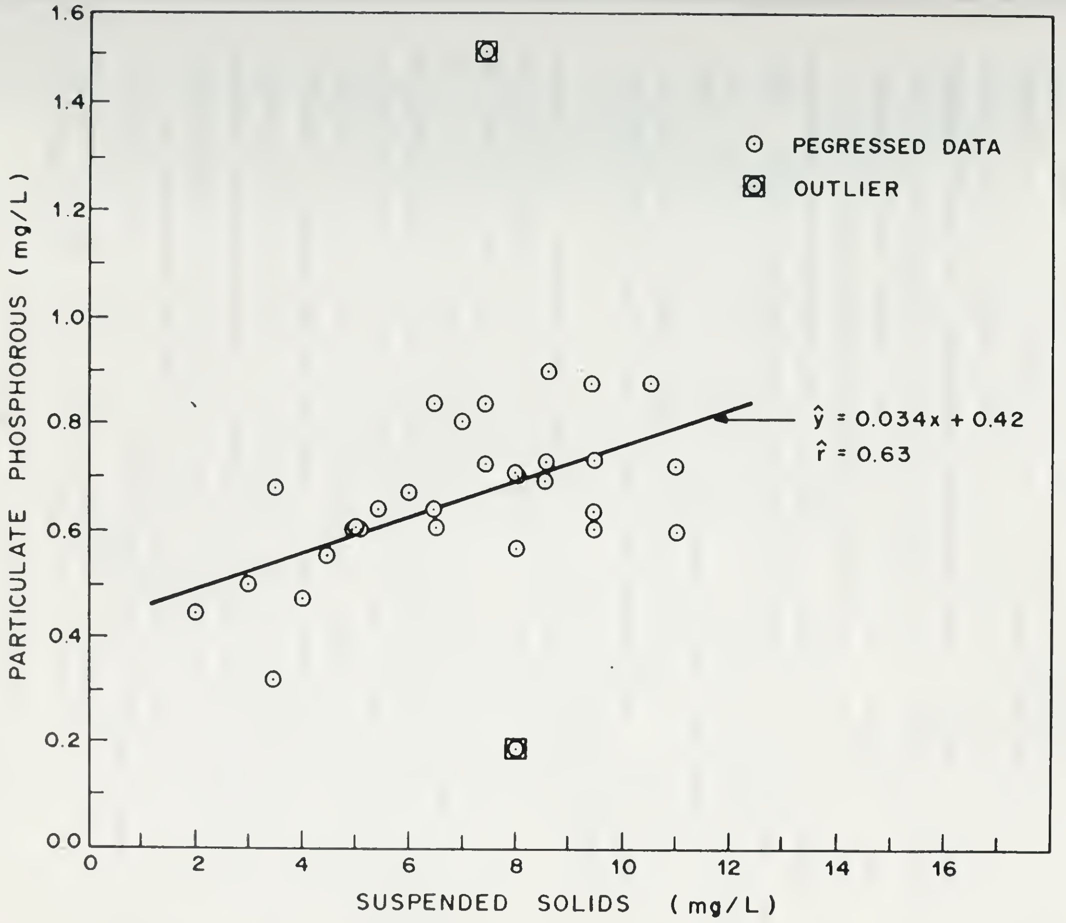


FIGURE 12-5 : RELATIONSHIP BETWEEN SECONDARY EFFLUENT PARTICULATE PHOSPHOROUS AND GRAVIMETRIC SUSPENDED SOLIDS FOR THE ESTEN LAKE WPCP

12.3 Conclusions of Esten Lake (Elliot Lake) WPCP Monitoring Program

The five-week monitoring program at the Esten Lake plant showed that a high quality effluent can be attained at the plant in terms of BOD_5, suspended solids and total phosphorus. Raw wastewater strength was low during the monitoring program based on the 24-hour composite influent samples despite the lower than average flowrate to the plant. The sampling program overlapped the annual summer shutdown of the mining industry in the town. This likely contributed significantly to the low average flowrate as summer vacations lead people to travel outside of the town. Periodic occurrences of high effluent total phosphorus (>1.0 mg/L) during the historical monitoring program resulted in part from equipment problems (alum feed pumps). These problems have been corrected.

Based on the loading rates at the plant, a high quality effluent should be expected. The plant is relatively new. Secondary clarifiers have been designed with sufficient surface area for peak flows of 2.6 times the design average flowrate.

In future, the continuous implementation of the ultrafiltration sample conditioning approach should provide for reliable operation for the Hach ortho phosphorus analyzer. Initial results suggest that the analyzer ultrafilter combination can provide an effective signal for control of alum dosage rate. The turbidity measurements are not likely required for alum dosage control, but provide for on-line detection of the effluent quality in terms of particulate phosphorus. Improved detection and control of the soluble phosphorus concentration could be obtained by measuring the secondary clarifier inlet concentration just downstream of the alum addition point. This would reduce lag time due to the secondary clarifier hold-up time and improve controller stability and response. The current alum dosage rate is relatively low and may be further optimized through implementation of a direct feedback control of the dosage rate.

13.0 SUMMARY OF PHASE II SAMPLING PROGRAM

13.1 Comparison to Historical Performance

The plant performance data collected from the Phase II sampling program period was compared to the historical performance (1981-1985) for each plant. Table 13.1 presents a summary of the 5-year (1981-1985) and 1985 averages compared to the sampling period averages for flows, and influent and effluent quality (BOD, TSS and TP) for each plant involved in the Phase II program.

In general, effluent BOD_5 concentrations for all plants were reported much lower for the sampling period (by CANVIRO) than historically (by MOE). This discrepancy was a result of the different methodologies used for measuring BOD at the MOE laboratory and at CANVIRO. At CANVIRO, inhibited BOD_5 tests were conducted which measured only the carbonaceous component of the biochemical oxygen demand. At MOE, uninhibited BOD_5 are conducted, measuring total (carbonaceous plus nitrogenous) BOD_5. Also, many of the plants had slightly lower influent BOD_5 concentrations than historically reported. This was undoubtedly the effect of raw wastewater dilution resulting from the frequent and heavy rainfall that occurred during the months of August and September 1986.

The high effluent quality reported historically in terms of BOD_5, suspended solids and total phosphorus was confirmed at Port Dalhousie WPCP, Fergus WPCP, Midland WPCP and Port Hope WPCP. At Trenton WPCP, the effluent quality in terms of suspended solids and phosphorus was much poorer than historically reported despite the weak influent concentrations of these parameters for this period. The weak influent and poor performance was probably due to the heavy rainfall during the sampling period, resulting is a high secondary clarifier surface load and a large amount of solids carryover.

The poor phosphorus removal performance historically reported for Collingwood WPCP, Duffin Creek WPCP, Humber WPCP and Main WPCP was confirmed by the results from the sampling program. At Humber WPCP and Main WPCP, effluent quality in terms of suspended solids and phosphorus was noticably worse during the sampling period than historically reported. The large amount of precipitation during the sampling period contributed to atypical plant operation. Plants that did not consistently comply historically with the effluent phosphorus limit of 1 mg/L which did consistently comply during

TABLE 13.1. COMPARISON OF SAMPLING PERIOD PERFORMANCE TO HISTORICAL PERFORMANCE

PLANT	DESIGN FLOW (10^3 m^3/d)	1981-1985 AVERAGE							1985 AVERAGE							SAMPLING PERIOD AVERAGE						
		FLOW (10^3 m^3/d)	INFLUENT			EFFLUENT			FLOW (10^3 m^3/d)	INFLUENT			EFFLUENT			FLOW (10^3 m^3/d)	INFLUENT			EFFLUENT		
			BOD	TSS	TP	BOD	TSS	TP		BOD	TSS	TP	BOD	TSS	TP		BOD	TSS	TP	BOD	TSS	TP
Port Dalhousie WPCP*	61.3	36.5	107	102	4.2	7.9	8.4	0.55	41.6	128	118	3.9	11.5	10.6	0.39	49.2	44	69	3.1	3.5	10.0	0.77
Fergus WPCP*	5.00	3.42	118	148	5.8	8.9	17.4	0.63	3.88	120	132	4.9	10.2	24.5	0.55	3.70	73	171	3.8	4.6	12.6	0.59
Midland WPCP*	13.6	9.25	76	175	5.0	8.2	6.3	0.48	10.9	68	132	4.5	3.0	6.4	0.57	10.4	55	164	5.8	2.6	6.2	0.69
Collingwood WPCP†	24.5	16.8	170	151	7.8	9.2	13.3	1.42	18.5	163	131	11.2	5.8	12.6	1.92	17.4	145	178	13.7	1.7	7.0	1.50
Moore Twp. WPCP†	1.45	2.05	115	122	7.0	6.4	9.9	0.85	2.85	124	138	7.9	9.1	9.6	0.85	2.41	77	120	5.2	2.3	7.0	0.60
St. Thomas WPCP†	26.8	17.8	80	121	4.6	7.1	7.4	1.15	18.9	89	145	5.2	6.4	8.3	1.14	21.1	78	160	4.9	2.2	7.0	0.75
Humber WPCP†	409.1	371.6	266	362	9.6	13.9	22.0	1.26	378.1	264	326	8.9	11.5	18.2	1.08	415.5	190	222	8.7	10.5	55	1.24
Main WPCP†	818.3	712.0	202	233	6.0	14.7	15.1	0.93	683.8	167	196	5.9	22.3	26.0	1.09	1262	87	177	5.5	5.7	58	2.01
Duffin Creek WPCP†	189.3	97.5	165	244	7.1	15.7	17.5	1.30	149.9	144	251	6.1	14.3	15.9	1.03	186.9	98	234	7.1	6.3	12.1	1.27
Port Hope WPCP*	9.08	8.01	93	78	3.5	5.5	5.8	0.64	9.59	111	57	1.9	6.0	5.4	0.56	9.64	26	47	2.9	3.0	6.8	<0.87
Trenton WPCP*	15.9	10.5	181	166	5.8	12.6	11.7	0.78	11.2	235	176	6.1	10.8	13.0	0.67	17.2	93	92	3.5	5.8	48	1.29
Esten Lake WPCP†	16.0	10.4	110	118	3.6	12.6	12.4	0.97	12.5	87	117	14.9	15.3	15.9	1.10	8.49	46	50	3.1	4.0	8.0	0.82

* Plants historically demonstrating good phosphorus removal performance.

† Plants historically demonstrating poor phosphorus removal performance.

the sampling program included Moore Twp. WPCP, St. Thomas WPCP and Elliot Lake WPCP. At Moore Twp. and St. Thomas WPCP, the factors affecting the better than historically reported performance included better characterization of the effluent from an increased frequency of sampling and length of sampling time, increases in chemical dosages for phosphorus removal and better overall plant operation. At Esten Lake, improved phosphorus removal performance was due to the elimination of previous problems associated with alum dosing equipment, and associated with sludge haulage and storage. Also, the recent addition of an on-line ortho-phosphate analyzer allowed better control of alum dosage.

13.2 Summary of the Key Factors Influencing Phosphorus Removal at Historically Complying Plants

Table 13.2 presents a summary of factors that affected total and soluble phosphorus removal at the five Phase II plants that have historically demonstrated consistent compliance to a 1 mg/L monthly effluent phosphorus concentration. During the sampling periods, all of the five plants had adequate metal to soluble phosphorus ratios (>1.5 mole/mole) to achieve relatively low effluent soluble phosphorus concentrations (<0.54 mg/L). Average to low secondary clarifier surface loadings produced low effluent suspended solids and low particulate phosphorus concentrations at all of the plants except Trenton WPCP. At this plant, the high clarifier surface loading produced solids carryover which resulted in particulate phosphorus to be a large component of the total effluent phosphorus concentration.

It can be concluded that the key factors affecting those plants that consistently demonstrated compliance to effluent phosphorus limits included sufficient chemical dosing to maintain low effluent soluble phosphorus levels and low effluent suspended solids concentrations resulting in low effluent particulate phosphorus concentrations.

13.3 Summary of Key Factors Influencing P Removal at Historically Non-Complying Plants

Table 13.3 presents a summary of the factors that affected the phosphorus removal performance during the Phase 2 program at the historically non-complying plants. The St. Thomas, Moore Twp. and Esten Lake plants demonstrated that effluent phosphorus concentrations could be maintained

TABLE 13.2. SUMMARY OF KEY FACTORS INFLUENCING P REMOVAL AT COMPLYING PLANTS

PLANT	% OF DESIGN FLOW	SECONDARY CLARIFIER SURFACE LOADING ($m^3/m^2.d$)	INFLUENT		CHEMICAL ADDITION			EFFLUENT			
			TP	SOL.P	USED	DOSAGE (mg/L)	METAL:SOL.P (Mole/Mole)	TSS (mg/L)	TP (mg/L)	SOL.P (mg/L)	PART.P (mg/L)
Pt. Dalhousie WPCP	75	15.3	3.1	2.1	$FeCl_3$	6.8	2.9	10.0	0.77	0.50	0.27
Fergus WPCP	74	16.3	3.8	2.1	$FeCl_2$	4.7	1.8	12.1	0.59	0.42	0.17
Midland WPCP	76	7.5	5.8	2.6	$FeCl_3$	3.7	1.5	6.2	0.69	0.54	0.16
Port Hope WPCP	106	31.2(old), 18.1(new)	2.9	2.0	Alum	2.4	1.5	6.8	<0.87	<0.39	I.D.
Trenton WPCP	110	42.4	3.5	2.0	$FeCl_2$	6.2	2.5	48	1.29	0.41	0.88

I.D. = Insufficient Data

TABLE 13.3. SUMMARY OF KEY FACTORS INFLUENCING P REMOVAL AT NON-COMPLYING PLANTS

PLANT	% OF DESIGN FLOW	SECONDARY CLARIFIER SURFACE LOADING ($m^3/m^2.d$)	INFLUENT		CHEMICAL ADDITION			EFFLUENT			
			TP	SOL.P	USED	DOSAGE (mg/L)	METAL:SOL.P (Mole/Mole)	TSS (mg/L)	TP (mg/L)	SOL.P (mg/L)	PART.P (mg/L)
Collingwood WPCP	71	11.7	13.7	10.6	Alum	8.1	0.9	7.0	1.48	1.00	0.38
Moore Twp. WPCP	166	11.8	5.2	3.6	Alum	7.1	2.4	7.0	0.60	0.30	0.30
St. Thomas WPCP	79	Avg. 22.6	4.9	2.3	Alum	3.6	2.0	6.5	0.75	0.55	0.20
Humber WPCP	102	22.8	8.7	2.9	$FeCl_2$	5.5	1.2	55	1.24	0.47	0.77
Main WPCP	154	62.9	5.5	2.4	$FeCl_2$	4.2	1.8	58	2.01	<0.27	1.74
Duffin Creek WPCP	98	17.4	7.1	2.7	Alum	2.8	1.3	12.1	1.27	0.73	0.54
Esten Lake WPCP	53	7.8	3.1	<2.0	Alum	1.6	1.1	8.0	0.82	0.54	0.28

below 1 mg/L during the sampling period. All three plants had adequate chemical addition to achieve good soluble phosphorus removal (to less than 0.55 mg/L) and achieved effluent particulate phosphorus concentrations of less than 0.3 mg/L. At Collingwood WPCP, high influent soluble phosphorus levels and low chemical dosing (Al:Sol.P of 0.9) were the key factors causing effluent soluble phosphorus concentrations averaging 1 mg/L. Similarly, at Duffin Creek, low dosing resulted in effluent soluble phosphorus concentrations averaging 0.73 mg/L.

At the two Toronto plants (Main and Humber), there was adequate chemical dosing to achieve soluble phosphorus concentrations of less than 0.5 mg/L. At the Main plant, extremely high clarifier surface loading (62.9 $m^3/m^2 \cdot d$) resulting from heavy rainfall caused solids carryover and average effluent suspended solids and particulate phosphorus concentrations of 55 mg/L and 1.74 mg/L, respectively. At the Humber plant, a solids washout problem was also evident, causing high effluent suspended solids (55 mg/L) and particulate phosphorus (0.77 mg/L). However, the secondary clarifiers were not as hydraulically loaded (22.8 $m^3/m^2 \cdot d$) as at the Main WPCP. Due to the fact that the performance of these plants was not typical during the sampling period, and the complexity of these plants, additional historical data analysis will be done in Phase 3 to identify the key factors affecting phosphorus removal at Humber WPCP and Main WPCP.

In summary, one of two main factors contributed to poor phosphorus removal. Either low chemical dosing did not allow consistently good removal efficiency of soluble phosphorus or poor effluent quality in terms of suspended solids, resulting most commonly from high secondary clarifier hydraulic loads, caused high effluent particulate phosphorus concentrations.